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Report to Congressional Committees

April 2019

COMBATING NUCLEAR TERRORISM

NRC Needs to Take Additional Actions to Ensure the Security of High-Risk Radioactive Material

GAO-19-468

GAO
Highlights

Highlights of GAO-19-468, a report to congressional committees

April 2019

COMBATING NUCLEAR TERRORISM

NRC Needs to Take Additional Actions to Ensure the Security of High-Risk Radioactive Material

Why GAO Did This Study

NRC is responsible for regulating the security of radioactive material in the U.S. Failure to secure this material could result in an RDD causing socioeconomic damage. The Consolidated and Further Continuing Appropriations Act, 2015 (Public Law 113-235) includes a provision for GAO to review NRC's security requirements for high-risk radioactive material. This report examines, among other things, (1) the extent to which radioactive security experts agreed that NRC's assessment of risk includes all relevant criteria, and (2) NRC's 2016 evaluation of its security requirements for high-risk radioactive material. GAO reviewed NRC policies and procedures, worked with the National Academies of Sciences to convene a meeting with 18 experts in radioactive security, and reviewed 3 recent Sandia studies. GAO used the views of security experts to define high risk, and they generally agreed that high risk includes both larger and some smaller quantities of radioactive materials.

What GAO Recommends

GAO is making three recommendations to NRC, including that it consider socioeconomic consequences and fatalities from evacuations as criteria for determining security measures and require additional security measures for smaller quantities of high-risk material. NRC generally disagreed with the recommendations, stating that GAO's evidence does not provide a sufficient basis for recommended changes. GAO continues to believe these recommendations are important.

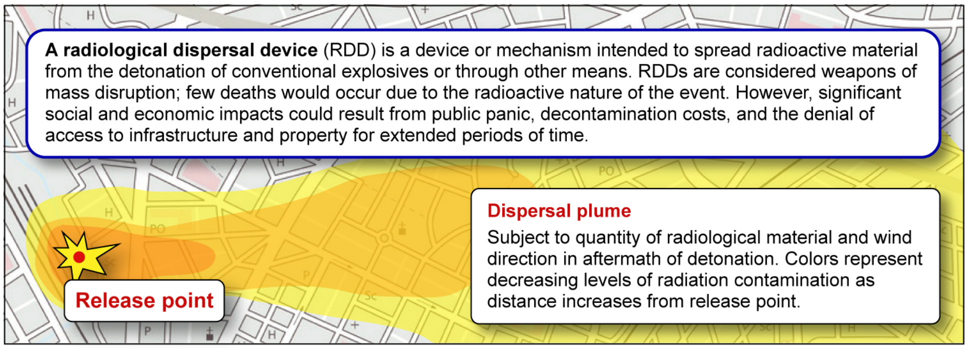
View GAO-19-468. For more information, contact David Trimble at (202) 512-3841 or trimbled@gao.gov.

What GAO Found

The 18 experts at a meeting GAO convened with the National Academies of Sciences generally agreed that the Nuclear Regulatory Commission (NRC) assessment of risks of radioactive material does not include all relevant criteria. NRC limits its criteria to prompt fatalities and deterministic health effects from radiation, which, according to the experts and recent studies, are unlikely to result from a radiological dispersal device (RDD). Two studies from Sandia National Laboratories (Sandia) measuring consequences of RDDs, released in 2017 and 2018, found that there would be no immediate fatalities from radiation. The experts at the meeting generally agreed that socioeconomic effects (e.g., relocations and clean-up costs) and fatalities that could result from evacuations are the most relevant criteria for evaluating the risks of radioactive material. The two Sandia studies found that a large RDD could cause about $30 billion in damage and 1,500 fatalities from the evacuation, and a considerably smaller RDD could cause $24 billion in damage and 800 fatalities from the evacuation. By considering socioeconomic impacts and fatalities resulting from evacuations in its criteria, NRC would have better assurance it was considering the more likely and more significant consequences of an RDD.

NRC's 2016 report evaluating its security requirements for high-risk radioactive material, required by Public Law 113-235, considered only the security of larger quantities of such material and not smaller quantities. Experts who attended GAO's meeting stated, and two 2018 Sandia studies agree, that if smaller quantities of certain radioactive material were used in an RDD, the impacts would be comparable to an RDD with a considerably larger amount of such material. For example, a 2018 study from Sandia found that malicious use of certain radioactive materials in smaller quantities could cause significant socioeconomic consequences. By requiring additional security measures for these smaller quantities of high-risk material, NRC can have better assurance that its security requirements are sufficient to secure all high-risk radioactive material from theft and use in an RDD.

Example of a Radiological Dispersal Device (RDD)



A radiological dispersal device (RDD) is a device or mechanism intended to spread radioactive material from the detonation of conventional explosives or through other means. RDDs are considered weapons of mass disruption; few deaths would occur due to the radioactive nature of the event. However, significant social and economic impacts could result from public panic, decontamination costs, and the denial of access to infrastructure and property for extended periods of time.

Dispersal plume

Subject to quantity of radiological material and wind direction in aftermath of detonation. Colors represent decreasing levels of radiation contamination as distance increases from release point.

Sources: GAO analysis of Nuclear Regulatory Commission and U.S. Department of Homeland Security data; VectorStock® (map).
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Abbreviations

DHS	Department of Homeland Security
FBI	Federal Bureau of Investigation
IAEA	International Atomic Energy Agency
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
PAG	Protection Action Guide
RDD	Radiological Dispersal Device

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April 4, 2019

The Honorable Lamar Alexander
Chairman
The Honorable Dianne Feinstein
Ranking Member
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

The Honorable Marcy Kaptur
Chairman
The Honorable Mike Simpson
Ranking Member
Subcommittee on Energy and Water Development, and Related Agencies
Committee on Appropriations
House of Representatives

Radioactive material is used in thousands of locations throughout the United States for medical, industrial, and research purposes, such as treating cancer, sterilizing food and medical instruments, and detecting flaws in metal welds. However, in the hands of terrorists, radioactive material—such as americium-241, cesium-137, cobalt-60, and iridium-192—could be used to construct a radiological dispersal device (RDD), also referred to as a “dirty bomb,” that uses conventional explosives to disperse radioactive material. Depending on the type, form, amount, and concentration of radioactive material used, an RDD could expose nearby individuals to radiation and increase their long-term risks of cancer. In addition, the evacuation and cleanup of contaminated areas could lead to serious socioeconomic costs, as individuals with homes and businesses in those areas may not be able to return for an extended period because of actual or feared contamination. Terrorist activity in the United States, Europe, and the Middle East has heightened concerns about RDDs and the need to better secure certain radioactive material. Furthermore, according to NRC, there exists a general credible threat on the malevolent use of radioactive materials in the United States. In addition, the International Atomic Energy Agency (IAEA) reported 3,068 unauthorized activities and events worldwide involving nuclear and radioactive material from 1993 to 2016, including incidents of trafficking and malicious use.[1]

The U.S. Nuclear Regulatory Commission (NRC) is responsible for licensing the commercial use and regulating the security of radioactive material in the United States. Prior to 2003, NRC did not have specific orders intended to address security, but its safety regulations included general provisions that licensees “secure from unauthorized removal or access” radiological sources in storage, and “control and maintain constant surveillance” over materials not in storage.[2] On March 19, 2013, NRC finalized a rule amending its regulations to establish security requirements for the use of risk-significant radioactive material. These amendments were codified as Part 37 of Title 10 of the *Code of Federal Regulations*, and are generally referred to as “Part 37”.[3] Part 37 brings together a set of previously issued orders into one set of requirements that addresses topics such as physical security, access control, monitoring and detection, incident response and coordination with local law enforcement authorities, and employee trustworthiness and reliability.[4]

In addition to NRC, the National Nuclear Security Administration (NNSA), the Department of Homeland Security (DHS), the Environmental Protection Agency (EPA), and the Federal Bureau of Investigation (FBI), among others, play a role in radioactive material security. According to

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[1] IAEA is the world’s central intergovernmental forum for scientific and technical cooperation in the nuclear field. The IAEA Incident and Trafficking Database is based on information reported by participating countries on illicit trafficking and other unauthorized activities involving nuclear and other radioactive materials. As of December 31, 2016, 134 countries were participating in the program, and 2016 is the most recent year for which this information is available.

[2] Standards for Protection against Radiation, 56 Fed. Req. 23360 (May 21, 1991) (amending 10 C.F.R. pt. 20). See specifically 10 C.F.R. §§ 20.1801, 20.1802. These provisions remain in effect.

[3] NRC defines risk-significant quantities of radioactive material as meeting the thresholds for category 1 and category 2 as included in the IAEA Code of Conduct on the Safety and Security of Radioactive Sources and in Part 37.

[4] Prior to Part 37, a series of NRC orders known as the Increased Controls introduced a number of security requirements. For example, a 2003 order addressed underwater and panoramic irradiators—which use gamma radiation for sterilization of products such as single use surgical equipment, medical supplies, and certain food products; a 2004 order addressed facilities manufacturing radioactive materials; and a 2007 order covered criminal background checks and fingerprinting.

NNSA's website, NNSA's Office of Radiological Security evaluates existing security systems at NRC licensees and provides upgrades and enhancements to existing security measures, removes and disposes of disused radioactive material, and works to reduce global reliance on high-activity radioactive material by promoting the development and adoption of non-radioisotopic alternative technologies.[5] DHS is the primary federal agency for implementing domestic nuclear detection efforts that support a managed and coordinated response to radioactive and nuclear threats. In the event of an emergency involving radioactive material, EPA's Radiological Emergency Response Team works with federal, state, and local agencies to monitor radioactivity and clean up affected areas. In addition, EPA has developed the Protective Action Guide (PAG) manual—which contains radiation dose guidelines that could trigger public safety measures, such as instructions to evacuate or stay indoors—to support actions necessary to protect people from unhealthy levels of radiation. The FBI maintains Weapons of Mass Destruction Coordinators at its 56 field offices who are responsible for building relationships with NRC licensees, including nuclear power plants, medical facilities, and academic institutions. The FBI also informs other federal agencies and licensees if it learns of a specific radioactive security threat.

We have previously reported on weaknesses in NRC and DHS policies and procedures to prevent unauthorized individuals from obtaining radioactive material. In July 2007, we established a fake business and obtained a real license, which we used to secure commitments to purchase a dangerous quantity of radioactive material.[6] To address this weakness in NRC licensing, we made three recommendations addressing how NRC ensured applicants for licenses are legitimate and that bad actors are not able to use a counterfeit license to acquire radioactive material. NRC agreed with and implemented all three recommendations, suspended its licensing program in 2007, and issued stricter interim pre-licensing guidance requiring site visits or face-to-face meetings prior to issuing new licenses. In September 2012, we found security weaknesses

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[5] NNSA is a semi-autonomous agency within the U.S. Department of Energy. The agency's Office of Radiological Security provides this assistance on a voluntary basis.

[6] GAO, *Nuclear Security: Actions Taken by NRC to Strengthen Its Licensing Process for Sealed Radioactive Sources Are Not Effective*, GAO-07-1038T (Washington, D.C.: July 12, 2007). In this case, we secured commitments for sufficient quantities of material that, combined, reached the threshold for a dangerous quantity of radioactive material.

at U.S. medical facilities,[7] and in a June 2014 report, we identified security challenges at industrial facilities.[8] In the September 2012 report, we made four recommendations, including a joint recommendation to NNSA and NRC to increase NNSA's outreach efforts and three recommendations to NRC to update its training, supplement its guidance, and provide licensees with specific security measures to secure radioactive material. NNSA and NRC agreed and implemented three of the recommendations, but NRC did not agree with and implement the recommendation to provide hospitals with specific measures to improve security. For the June 2014 report, we made four recommendations, including, among other things, directing NRC to reconsider the definition used for collocation of radioactive material and conduct an assessment of the Trustworthiness and Reliability process used to protect against an insider threat.[9] NRC agreed and implemented all four recommendations made in the report.

Furthermore, in July 2016, we again tested the rigor of NRC's licensing process by establishing three fake businesses and successfully obtained a real license for one of these businesses. We then used that license to obtain commitments to purchase a quantity of radioactive material that would be dangerous if not properly secured.[10] In the 2016 report, we made three recommendations directing NRC to take steps to better track certain radioactive material, confirm the validity of transfers of material, and consider on-site security reviews for unknown applicants to ensure material cannot be purchased without a verified license. NRC stated that it understood our recommendations and has not yet implemented them. In January 2018, we found gaps in how DHS's Customs and Border

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[7] GAO, *Nuclear Nonproliferation: Additional Actions Needed to Improve Security of Radiological Sources at U.S. Medical Facilities*, GAO-12-925 (Washington, D.C.: Sept. 10, 2012).

[8] GAO, *Nuclear Nonproliferation: Additional Actions Needed to Increase the Security of U.S. Industrial Radiological Sources*, GAO-14-293 (Washington, D.C.: June 6, 2014).

[9] Before a licensee can grant an employee unescorted access to larger quantities of radioactive material, Part 37 requires the licensee to, among other things: (1) conduct employment and education background checks; (2) perform an identification and criminal history check that includes taking the employee's fingerprints and sending them to NRC, which forwards the fingerprints to the FBI; and (3) determine that the individual is trustworthy and reliable. These measures are intended to mitigate the risk of an insider threat—an employee or someone else with authorized access who might try to steal, tamper with, or sabotage radioactive materials.

[10] GAO, *Nuclear Security: NRC Has Enhanced the Controls of Dangerous Radioactive Materials, but Vulnerabilities Remain*, GAO-16-330 (Washington, D.C.: July 1, 2016).

Protection (CBP) ensures only properly licensed radioactive material is imported into the United States.[11] In that report, we made three recommendations, directing CBP to develop a monitoring system for how they verify licenses for imported radioactive material, conduct an assessment of the information not included in its automated alert for radioactive material, and better identify shipments of material that pose the greatest risk. CBP agreed with our recommendations and has undertaken its assessment for verifying licenses, but has not yet developed a monitoring system to ensure compliance nor developed a system to identify material that poses the greatest risk.

The Consolidated and Further Continuing Appropriations Act, 2015 (Public Law 113-235) included a provision for NRC to evaluate the effectiveness of its current security requirements to protect high-risk radioactive material.[12] NRC conducted this evaluation and issued its report in December 2016.[13] In addition, Public Law 113-235 also included a provision for us to review NRC's security requirements for high-risk radioactive material.[14] Public Law 113-235 also required us to work with an independent group of radioactive security experts as part of our review. This report (1) describes how NRC assesses risk when establishing security requirements for radioactive material; (2) examines the extent to which radioactive security experts agreed that NRC's assessment of risk includes all relevant criteria for establishing security requirements; and (3) examines NRC's 2016 report evaluating its security requirements for high-risk radioactive material. This report is a public

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[11] GAO, *Nuclear Security: CBP Needs to Take Action to Ensure Imported Radiological Material Is Properly Licensed*, GAO-18-214 (Washington, D.C.: Jan. 10, 2018).

[12] Pub. L. No. 113-235, Div., Tit. IV § 403(a), 128 Stat. 2130, 2331 (2014).

[13] Nuclear Regulatory Commission, *Report to Congress Under Public Law 113-235, Effectiveness of Part 37 of Title 10 of the Code of Federal Regulations*, (Washington, D.C.: December 14, 2016).

[14] Pub. L. No. 113-235, Div. D, Tit. IV § 403(b), 128 Stat. 2130, 2331 (2014). NRC completed its report on December 14, 2016. (Nuclear Regulatory Commission, *Report to Congress under Public Law 113-235: Effectiveness of Part 37 of Title 10 of the Code of Federal Regulations*" (Washington, D.C.: Dec. 14, 2016)). In its review, NRC interpreted high risk to mean the largest quantities of radioactive material (categories 1 and 2). As discussed later in this report, we used the views of security experts to define high risk, and these experts generally agreed that high risk includes both larger quantities and some smaller quantities of radioactive materials.

version of an Official Use Only report that we issued in March 2019.[15] NRC deemed some of the information in our March report to be Official Use Only, which must be protected from public disclosure. Therefore, this report omits all Official Use Only information about types and amounts of radioactive material. Although the information provided in this report is more limited, the report addresses the same objectives as the Official Use Only report and uses the same methodology, which we have described in less detail to omit references to Official Use Only information.

To describe how NRC assesses risk when establishing security requirements for high-risk radioactive material, we reviewed documents addressing how NRC evaluates an RDD, NRC's study evaluating Part 37 in response to Public Law 113-235, and NRC's analysis of the risks posed by high-risk radioactive material. In addition, we interviewed agency officials at NRC, NNSA, DHS, EPA, and FBI, as well as academics, agreement state officials,[16] and security managers from industry about the risks associated with different categories of radioactive material and how NRC regulates this material.

To examine the extent to which radioactive security experts agreed that NRC's assessment of risk includes all relevant criteria for establishing security requirements, we partnered with the National Academies of Sciences to identify a balanced group of leading experts in the field of radioactive security and related issues. The National Academies helped us identify and select 18 experts representing a broad range of stakeholders; the experts included federal agency officials, agreement state officials, academics, representatives of nonprofit organizations, licensees, industry representatives, international regulators, national laboratory specialists, and economists. We convened these experts for a 2-day meeting in July 2018. During the meeting, we introduced the threat of malevolent use of radioactive material, and we asked the experts to

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[15] GAO, *Combating Nuclear Terrorism: NRC Needs to Take Additional Actions to Ensure the Security of High-Risk Radioactive Material*, GAO-19-258SU (Washington, D.C.: Mar. 14, 2019).

[16] The Atomic Energy Act of 1954 gives the Nuclear Regulatory Commission regulatory authority over domestic industrial, medical, and research uses of radioactive materials. The act also authorizes NRC to enter into agreements with states (called agreement states) so they assume, and NRC relinquishes, regulatory authority over specified radioactive materials. The remaining states are known as NRC states. NRC and agreement states license, monitor, track, and require security for radioactive materials in order to protect both workers and the public from exposure to hazardous levels of radiation generated by the activities of licensees.

focus their discussion on the potential consequences of an RDD, the vulnerabilities of radiological materials under current security requirements, and whether current security requirements were sufficient given these consequences and vulnerabilities. In addition, we asked the experts the reasons various radionuclides should be considered high risk, the reasons these radionuclides should not be considered high risk, and on balance, whether these radionuclides should be considered high risk. During the first part of our meeting, we asked experts about a list of potential consequences from an RDD, the reasons to account for these consequences when regulating radiological sources, the reasons not to account for these consequences, and on balance, whether these consequences should be accounted for when determining regulation for radiological sources. During the second part of the meeting, we asked experts to consider four scenarios, each of which was defined by a specific radioactive material stored under a given set of security controls. For each scenario, we asked experts to discuss the primary vulnerabilities and whether Part 37 security requirements were sufficient given those vulnerabilities and the potential consequences. After the expert meeting, we conducted a thematic analysis of the information gathered to better understand the consequences of an RDD using various radioactive materials.

At our expert meeting, we sought to gather all perspectives on the issues, and the moderators ensured that experts with differing perspectives had the opportunity to voice their opinions. We did not include techniques designed to reach consensus on any topic of discussion because of the diverse composition of experts and the goal of having a full discussion on all points of view. Furthermore, some experts brought unique expertise to the group, and their opinions on certain topics carried more weight than others with different areas of expertise.[17] For example, a point on the potential for radioactive material to contaminate a specific area might have more weight coming from an expert from a national laboratory than from an expert with an economics background. Experts did not speak on every topic and did not have the same level of expertise on every topic, and the meeting format was not designed to quantify the experts' comments. Therefore, we do not report the number of experts who

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[17] GAO, *Government Auditing Standards, 2018 Revision*, GAO-18-568G (Washington, D.C.: July. 2018). According to government auditing standards, testimonial evidence obtained from an individual who is not biased and has direct knowledge about the area is generally more reliable than testimonial evidence obtained from an individual who is biased or has indirect or partial knowledge about the area.

agreed or disagreed with various statements. Instead, through our thematic analysis, we determined that during the expert meeting, experts made two types of statements on topics with varying degrees of agreement or corroboration, which we refer to as either “strong evidence” or “evidence of varying viewpoints.” We considered statements as being strong evidence when they were made by multiple experts, when the supporting evidence offered by the experts was sound, when they were corroborated by other forms of evidence, and when we did not identify evidence that contradicted it. In this report, we refer to such statements as “experts generally said,” “experts generally told us,” or “experts generally agreed.” We considered statements as representing various viewpoints when credible experts on a given topic provided conflicting viewpoints, when we found the evidence from both sides to be sound, evidence from both sides was consistent with other evidence, and experts who made statements had strong expertise in the area. We refer to these statements as “some experts said X while other experts said Y.” Appendix II provides more detail about our analysis.

In addition, we interviewed officials and obtained key documents from NRC, NNSA, DHS, FBI, and Sandia National Laboratories (Sandia) on the risk associated with radioactive material. We reviewed academic research and our previous reports on the components of risk, a 2017 Sandia economic impact study, and two studies Sandia produced for us in 2018 describing the consequences of RDDs involving a category 1 and category 3 quantity of a radioactive isotope of concern.[18] We also traveled to Sandia to interview laboratory officials on the risks associated with various radioactive materials that could be used in an RDD.

To examine potential weaknesses in NRC’s security requirements that were established to ensure high-risk radioactive material is safeguarded, we reviewed previous GAO reports and interviewed officials within the federal government and representatives of industry to better understand current security requirements and practices. Specifically, we were contacted by a working group that represents manufacturers of radioactive material and companies that use large quantities of radioactive material in their industrial processes. We spoke with these officials on various occasions throughout the engagement, and during the interviews, we solicited these officials’ and industry representatives’

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[18] Regarding the different categories of radioactive materials, the International Atomic Energy Agency published a system that ranked quantities of individual radionuclides into 1 of 5 categories on the basis of their potential to harm human health.

opinions on whether NRC's current security requirements are sufficient for ensuring the security of high-risk radioactive material.

We conducted this performance audit from December 2017 to March 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

In September 2003, the United States and other nations endorsed IAEA's Code of Conduct, which established basic principles and guidance to promote the safe and secure use of radioactive material. The Code of Conduct applies to category 1, 2, and 3 quantities of radioactive material—all of which are potentially dangerous to human health and could, if not properly controlled, cause permanent injuries or death to a person who handled or was otherwise in contact with them.[19] IAEA's system considers radioactive material dangerous when gathered in close proximity to people in sufficient quantity and for a sufficient time to cause direct human health effects. NRC, working with the Department of Energy, developed a list of 16 radionuclides of concern that, if gathered in category 1 or 2 quantities, pose the greatest risk of being used by terrorists to make an RDD.[20] Of these 16 radionuclides of concern, 4 are most prevalent in the U.S. economy: americium-241, cobalt-60, cesium-137, and iridium-192.

Since the terrorist attacks in September 2001, concerns have grown that terrorists could obtain and use radioactive material and build an RDD.

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[19] A category 1 quantity of a given radionuclide, the most dangerous, is defined as an amount 1,000 times or more than the amount necessary to cause permanent human injury; a category 2 quantity is still considered dangerous to human health and is defined as an amount at least 10 times but less than 1,000 times the amount necessary to cause permanent human injury. A category 3 quantity of a given radionuclide is defined as at least the minimum amount, but less than 10 times the amount, sufficient to cause permanent injury. Category 4 and 5 quantities of radioactive materials are unlikely to cause permanent injury.

[20] The 16 radionuclides of concern include: americium-241, americium-241/beryllium, californium-252, cesium-137, cobalt-60, curium-244, gadolinium-153, iridium-192, plutonium-238, plutonium-239/beryllium, promethium-147, radium-226, selenium-75, strontium-90, thulium-170, and ytterbium-169.

The risk of an RDD is determined by the function of three components: threat, vulnerability, and consequence. Threat is generally defined as entities or actions with the potential to cause harm—including terrorist attacks.[21] According to NRC officials, there is a general credible threat of malevolent use of radioactive materials. The second component of RDD risk, vulnerability, includes physical features or operational attributes that render an asset open to exploitation, including gaps in security measures such as gates, locks, perimeter fences, and computer networks. Finally, the third component of RDD risk, consequence, includes the effects of terrorist attacks or natural disasters that result in losses to public health and safety and the economy. Taken together, the three components make up a “risk triplet,” which is shown in figure 1.

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[21] Threat information is typically classified, and therefore, we do not go into specifics on the threat of terrorists stealing radioactive material for use in an RDD in this report.

Figure 1: The “Risk Triplet” for Radioactive Material That Could Be Used in a Radiological Dispersal Device (RDD)

Source: GAO analysis of the Department of Homeland Security information. | GAO-19-468

The consequences of detonating an RDD would depend on the quantity and type of radioactive material used and the size and characteristics of the area in which the material was dispersed. An example of the consequence of an RDD occurred in 1987 when two people in Goiânia, Brazil, found an abandoned medical machine containing 1,400 curies of cesium-137. The individuals, who were unaware of the nature of the radioactive material, extracted it from the machine and distributed the material to several families, causing 20 people to be hospitalized and four deaths. The very high internal and external contamination was caused by the way they handled the cesium-137, including rubbing their skin with the material and eating with contaminated hands. In addition, 112,000 people in the surrounding area were monitored for exposure to radiation, of which 249 were found to be internally or externally contaminated. The accident also contaminated 85 houses and required the demolition of homes and other buildings, generating 3,500 cubic meters of radioactive waste. This example shows the range of consequences from the dispersal of radioactive material, from fatalities to socioeconomic effects.[22] Potential consequences of an RDD are outlined in figure 2.

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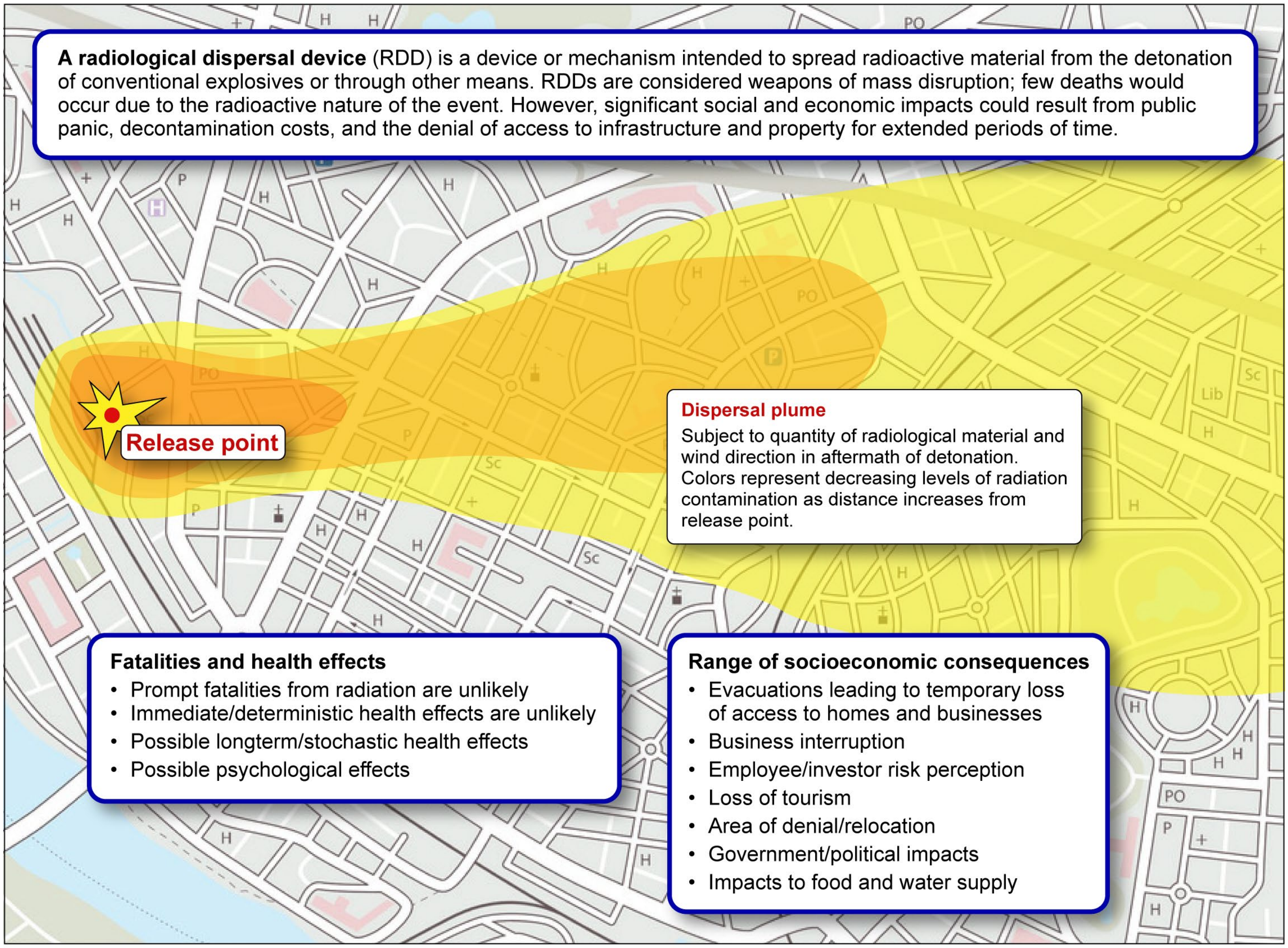
[22] Deterministic health effects occur as a direct result of exposure to certain levels of radiation. They are defined as the dose above which signs and symptoms of the effect on a specific organ or tissue can be detected. Examples of deterministic health effects could include irreversible skin damage, hair loss, and sterility.

Figure 2: Potential Consequences of a Radiological Dispersal Device (RDD)



A radiological dispersal device (RDD) is a device or mechanism intended to spread radioactive material from the detonation of conventional explosives or through other means. RDDs are considered weapons of mass disruption; few deaths would occur due to the radioactive nature of the event. However, significant social and economic impacts could result from public panic, decontamination costs, and the denial of access to infrastructure and property for extended periods of time.

Dispersal plume

Subject to quantity of radiological material and wind direction in aftermath of detonation. Colors represent decreasing levels of radiation contamination as distance increases from release point.

Fatalities and health effects

- Prompt fatalities from radiation are unlikely
- Immediate/deterministic health effects are unlikely
- Possible longterm/stochastic health effects
- Possible psychological effects

Range of socioeconomic consequences

- Evacuations leading to temporary loss of access to homes and businesses
- Business interruption
- Employee/investor risk perception
- Loss of tourism
- Area of denial/relocation
- Government/political impacts
- Impacts to food and water supply

Sources: GAO analysis of Nuclear Regulatory Commission and U.S. Department of Homeland Security data; VectorStock® (map). | GAO-19-468

Depending on the size and radioactivity of an RDD, the affected population could be evacuated and possibly relocated.[23] EPA's Protective Action Guide (PAG) presents radiation dose guidelines that are used by

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[23] The ability of radioactive material to contaminate an area is known as the "power to contaminate."

federal agencies to protect people from unhealthy levels of radiation.[24] According to the PAG, evacuation is recommended when there is enough radiation to reach 5.0 rem over the first 4 days.[25] The PAG also outlines actions that can be taken in response to projected radiation dose rates, including evacuation, shelter in place, relocation, and avoidance of drinking water or food supplies. The PAG does not consider a specific geographic area, such as a square kilometer, when recommending evacuation.

Domestically, the Atomic Energy Act of 1954, as amended, gives NRC primary responsibility for regulating most domestic industrial, medical, and research uses of radioactive material to protect public health and safety, among other things. NRC is composed of five Commissioners (the Commission) appointed by the President and confirmed by the Senate for 5-year terms. One of the Commissioners is designated by the President to be the Chairman and official spokesperson of the Commission. According to NRC's website, the Commission formulates policies, develops regulations governing nuclear reactor and nuclear and radioactive material safety, issues orders to licensees, and adjudicates legal matters. Issues before the Commission are decided by majority vote, and the Commission directs subsequent actions be implemented by NRC staff.

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[24] According to NRC officials, protective action decisions might not be made by federal agencies, but rather by state or local officials in the area where the event occurs, typically with input from relevant federal agencies.

[25] Rem is a standard unit to measure effective dose from radiation. After the first four days, the standard changes to 2.0 rem in the first year or 0.5 rem in any subsequent year.

NRC Periodically Assesses Risk When Establishing Security Requirements for Radioactive Material

When establishing security requirements for radioactive material, since 2004, NRC has assessed the risks of such material based on the potential of that material to cause prompt fatalities and the deterministic health effects from its radiation;[26] it has not used socioeconomic consequences as a basis for establishing regulations related to the security of radioactive material. Moreover, in response to the recommendations we made in 2016 that NRC should better track category 3 quantities of radioactive material,[27] NRC staff assessed whether they should require additional security measures for category 3 radioactive material and determined that such material did not merit additional security measures.

NRC Considers Prompt Fatalities and Deterministic Health Effects When Assessing the Risk of an RDD and Does Not Consider Socioeconomic Consequences

Since 2004, NRC has assessed the risks of radioactive material based on the potential of that material to cause prompt fatalities and deterministic health effects from radiation. NRC on several occasions reassessed and repeatedly reaffirmed its use of the occurrence of prompt fatalities and deterministic health effects as its primary criteria for measuring the consequences of an RDD, including when developing its decision-making framework in 2004, reviewing its regulatory framework after the Fukushima nuclear disaster in 2011, and in its 2014 response to recommendations from the Radiation Source Protection and Security Task Force (the Task Force).

NRC first considered prompt fatalities from radiation as criteria for measuring consequences in November 2004 when developing its decision-making framework for evaluating vulnerabilities for theft of radioactive material.[28] Specifically, in 2004 NRC staff recommended that the Commission approve a decision-making framework that assessed risk

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[26] NRC defines prompt fatalities as deaths from the acute effects of radiation that may occur within a few months of the exposure. Prompt fatalities would usually result from acute exposures (large exposure received over a short period of time). According to NRC, deterministic health effects are defined as consistent with the principles of determinism, which hold that specific causes completely and certainly determine effects of all sorts. Furthermore, severe deterministic effects could be fatal or life threatening or result in permanent injury that reduces quality of life.

[27] GAO-16-330.

[28] NRC developed its decision-making framework as a tool to determine the appropriate level of mitigation strategies required for a given threat scenario. The decision making framework is separate from NRC's overall regulatory framework.

based on prompt fatalities from radiation.[29] In the Commission Paper, NRC staff stated that the framework would employ the consequence criteria of preventing prompt fatalities from radiation exposure, but they also recognized that including additional consequence criteria, such as land contamination, might be warranted.[30] They also pointed out that DHS's Risk Analysis and Management for Criteria Asset Protection framework used criteria including economic, environmental, and loss of output of production capability, among other things.[31] In January 2005, the Commission approved using prompt fatalities from radiation for measuring consequence.[32] In its decision, the Commission also said that NRC staff should not independently develop criteria and standards for other consequences, such as land contamination and economic impacts.

After the Fukushima nuclear disaster in 2011, NRC staff again considered broadening the criteria for assessing risk to include socioeconomic impacts. Specifically, in an August 2012 analysis presented to NRC commissioners in response to Fukushima that addressed whether NRC's regulatory framework should be modified to consider economic consequences, NRC staff noted that NRC's existing requirements have the effect of minimizing economic consequences by preventing or mitigating events that could lead to a radioactive release.[33] The analysis prepared by NRC staff recommended improving guidance for estimating offsite economic costs based on up-to-date data. In March 2013, the Commission approved the staff's recommendation to provide enhanced

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[29] NRC staff generally submit Commission Papers, also known as SECY Papers, to the Commission to inform them about policy, rulemaking, and adjudicatory matters.

[30] Nuclear Regulatory Commission, *SECY-04-0222: Policy Issue: Notation Vote: Decision-Making Framework for Materials and research and Test Reactor Vulnerability Assessments* (Washington, D.C.: November 24, 2004).

[31] DHS's Risk Analysis and Management for Criteria Asset Protection framework is a framework for analyzing and managing the risks associated with terrorist attacks against critical infrastructure assets.

[32] Nuclear Regulatory Commission, *SRM-SECY-04-0222—Memo to Executive Director for Operations* (Washington, D.C.: January 19, 2005).

[33] Nuclear Regulatory Commission, *SECY-12-0110—Policy Issue (Notation Vote): Consideration of Economic Consequences Within the U.S. Nuclear Regulatory Commission's Regulatory Framework* (Washington, D.C.: August 14, 2012).

guidance but found that socioeconomic consequences should not be considered.[34]

In an August 2012 report, NRC staff considered a recommendation of the Task Force for Radiation Source Protection and Security that NRC reevaluate its protection and mitigation strategies, and the staff determined that considering socioeconomic consequences and contamination would constitute a significant and unnecessary change in the underpinning assumptions NRC used to determine the consequence of an RDD.[35] This was in response to a 2010 report by the Task Force, which is chaired by NRC. In its report, the Task Force reevaluated consideration of consequences from an RDD and recommended that NRC consider including socioeconomic impacts as criteria for measuring the consequences of RDDs.[36] Specifically, the Task Force expanded its consideration of consequences beyond prompt fatalities from radiation and deterministic health effects to include economic, social, and psychological consequences.[37] The Task Force noted that an RDD is unlikely to cause prompt fatalities from radiation and recommended that the federal government reevaluate its protection and mitigation strategies to protect against a significant RDD and include economic consequences.[38] In their response, NRC staff said that they would need additional direction from the Commission to consider examining alternative consequences. NRC staff presented their recommendation that NRC not consider changing the policy to include consideration of

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[34] Nuclear Regulatory Commission, *SRM-SECY-12-0110—Memo to Executive Director for Operations* (Washington, D.C.: March 20, 2013).

[35] Nuclear Regulatory Commission, Policy Issue (Notation Vote): Consideration of Economic Consequences Within the U.S. Nuclear Regulatory Commission's Regulatory Framework, *Enclosure 4, Radiation Source Protection and Security Trask Force, Recommendation 2*. (Washington, D.C.: August 14, 2012).

[36] The Task Force was established by the Energy Policy Act of 2005 and is chaired by NRC. It includes members from 12 federal agencies, the Conference of Radiation Control program Directors, and the Organization of Agreement States. The Task Force provides specific recommendations to the President and Congress relating to the security of radioactive sources in the United States from potential terrorist threats, including acts of sabotage, theft, or use of a radiation source in an RDD.

[37] Nuclear Regulatory Commission, Radiation Source Protection and Security Task Force, *The 2010 Radiation Source Protection and Security Task Force Report* (Washington, D.C.: August 11, 2010).

[38] The Task Force defined a significant RDD as capable of contaminating 1 km^2 at 2 rem for the first year.

socioeconomic consequences to the Commission in January 2014, reiterating the staff's view that Part 37 provides adequate security protection against a significant RDD.[39] The NRC staff also concluded that the current protection and security framework and posture adequately protects against contamination and resulting economic consequences.

NRC Assessed the Risk Associated with Category 3 Material and Determined That No Additional Security Measures Are Needed

In 2016, NRC established the Category 3 Source Security and Accountability Working Group (the Working Group) in response to our 2016 recommendations to NRC to better track dangerous quantities of radioactive material.[40] This group issued a report in 2017 assessing whether NRC should require additional security measures for category 3 material and determined that such material did not meet the threshold of prompt fatalities and deterministic health effects set by NRC, and therefore, did not require additional security measures.[41] As part of its analysis, the Working Group stated that a category 2 quantity of a certain radioactive material would not be sufficient to achieve an RDD of consequence that would cause deterministic health effects.[42] NRC officials also told us that there is not enough of this same radioactive material in the United States to create an RDD of consequence even if all of it was used in an RDD. The Working Group also concluded that there is no evidence of adversarial interest in acquiring category 3 quantities of material by theft, that security weaknesses at facilities that contain

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[39] Nuclear Regulatory Commission, *U.S. Nuclear Regulatory Commission's Proposed Response to Address Recommendation 2 from the 2010 Radiation Source Protection and Security Task Force Report* (Washington D.C.: January 14, 2014).

[40] GAO-16-330. In the 2016 report, we made three recommendations directing NRC to take steps to better track dangerous quantities of radioactive material, confirm the validity of transfers of material, and consider on-site security reviews for unknown applicants to ensure material cannot be purchased without a verified license. NRC has not yet implemented these recommendations.

[41] Nuclear Regulatory Commission, *SECY-17-0083, Policy Issue, Notation Vote, Re-Evaluation of Category 3 Source Security and Accountability in Response to SRM-COMJMB-16-0001* (Washington, D.C., August 18, 2017). The Working Group looked at, among other things, the ability to obtain a valid license using a fictitious company, the ability to alter a valid license or produce a counterfeit license to obtain radioactive material, and the aggregation of category 3 radioactive materials to a category 2 quantity.

[42] Nuclear Regulatory Commission, *SECY-17-0083, Re-Evaluation of Category 3 Source Security and Accountability in Response to SRM-COMJMB-16-0001, Enclosure 4* (Washington, D.C., August 18, 2017). As discussed later in our report, new research from Sandia found that a category 3 quantity of a certain radioactive material could trigger an evacuation and result in significant socioeconomic consequences.

category 3 quantities of radioactive material had not increased since first evaluated by NRC, and the consequences of an RDD using category 3 material are not significant enough to require additional security measures.

Based on the findings of the working group's report, NRC staff recommended that the Commission not amend regulations to require license verification of category 3 radioactive material or impose security requirements to prevent the aggregating of category 3 material to a category 2 quantity. The report did recommend that the Commission approve the pursuit of rulemaking to require safety and security equipment be in place before granting a license for an unknown entity and clarify license verification methods for transfers involving quantities of radioactive material below the category 2 threshold.

Experts Generally Agreed That NRC's Assessment of Risk Does Not Include All Relevant Criteria for Establishing Security Requirements

The experts we convened with assistance from the National Academies generally agreed that NRC's assessment of risk does not include the all relevant criteria for establishing security requirements.[43] The experts at our meeting generally agreed that prompt fatalities from radiation and deterministic health effects are not the only relevant criteria for determining the consequences of an RDD, which recent studies we reviewed support. These experts and studies generally agreed that socioeconomic effects and fatalities from subsequent evacuations are relevant criteria for assessing the consequences of an RDD.

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[43] This section reflects comments that experts in radiological security provided regarding the potential consequences of an RDD at the meeting we convened at the National Academy of Sciences. We asked them to discuss the reasons to account for the consequence in the regulation of radioactive materials, the reasons not to account for the consequence, and on balance, whether the consequence should be accounted for. Please see appendix II for additional details on our methodology.

Experts Generally Agreed and Studies Support That Prompt Fatalities and Deterministic Health Effects Have Limited Value as Criteria

The experts at our meeting generally agreed that using prompt fatalities and deterministic health effects from radiation as the basis for analyzing consequence have limited value to NRC as criteria for determining the consequences of an RDD, as they are unlikely to occur in the event of an RDD. Experts generally said at our meeting expressed the opinion that NRC is not focusing on all relevant criteria for assessing consequence. For example, one expert from the regulatory community said that prompt fatalities are an unlikely consequence of an RDD. Another expert affiliated with users of radioactive material noted that deterministic health effects from an RDD are limited. Finally, a security expert said that it would be difficult to kill large numbers of people with an RDD, and therefore prompt fatalities are not a good measure of consequence. Another expert pointed out that NRC's current criteria would be unlikely to support regulating category 1 and 2 materials since an RDD with these materials is unlikely to cause prompt fatalities. He added that this creates a disconnect where category 3 material is ignored, but NRC regulates category 1 and 2 material even though category 1 and 2 materials do not meet NRC's criteria of causing prompt fatalities and deterministic health effects.

Recent studies from Sandia also show that prompt fatalities and deterministic health effects are unlikely to result from an RDD. Specifically, Sandia completed two studies in 2017 and 2018 that modeled an RDD blast and evaluated the potential consequences in New York City. The 2017 study modeled the potential consequences of a category 1 quantity of radioactive material detonated in an RDD and estimated that there would likely be no prompt fatalities from radiation. The 2018 study undertook the same analysis with a category 3 quantity of radioactive material and estimated that it would also produce no prompt fatalities from radiation.

Experts Stated and Studies Support That Socioeconomic Effects and Fatalities Resulting From Evacuations Are Relevant Criteria for Determining the Consequences of an RDD

The experts who participated in our meeting discussed what type of consequences should be considered and generally agreed that socioeconomic effects and fatalities from subsequent evacuations, rather than prompt fatalities and deterministic health effects, are relevant criteria for NRC to consider when assessing the consequences of an RDD, which recent studies we reviewed support. For example, one expert said that while deterministic health effects from an RDD are limited, socioeconomic impacts are significant. Another expert said that the main point of a terrorist detonating an RDD is to create economic effects, not deterministic health effects. This expert added that the dispersal of radioactive material would result in low-level radiation scattered across an area, leading to socioeconomic consequences. A participating expert from the regulatory community said that it is difficult to quantify socioeconomic effects. Furthermore, the expert said that any model used to determine regulation by predicting consequence must be reproducible.

The federal government has recently taken steps to better understand the socioeconomic costs associated with an RDD. For example, Sandia studies completed in 2017 and 2018 estimated socioeconomic costs for RDDs with category 1 and category 3 quantities of radioactive material. The 2017 study that modeled a category 1 quantity of radioactive material estimated that the socioeconomic impact on the national gross domestic product would be approximately $30 billion.[44] The 2018 study, which substituted a category 3 quantity of radioactive material, estimated the socioeconomic impact on gross domestic product at $24 billion.[45] One expert noted that the estimates may be understated. Specifically, the 2017 Sandia study took into account that the facades of some buildings in New York City could be replaced, which would aid cleanup and reduce socioeconomic costs. However, one expert who attended our meeting said that New York City may be a best-case example of an urban target because the city has solid response plans and modern buildings with facades that can be removed more easily than those in other cities. This expert said these factors likely lead to an optimistic calculation of socioeconomic consequence in the study, due to the preparation and resilience posture of New York City, creating a best-case scenario regarding cleanup that may not accurately quantify costs in other cities. In this expert's view, the federal government may also be underestimating the economic consequences of an RDD by not accounting for the potential that local cleanup standards may be more stringent than the

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[44] Trost, Lawrence C., Vanessa Vargas, Drake Warren, Robert Knowlton, William Fogleman, and Emma Grazier. "(U) Economic Impacts of an RDD Incident", Sandia National Laboratories, March 2018.

[45] Sandia National Laboratories, *A Comparison Study of RDD Economic Impacts*, SAND2018-7945, (Albuquerque, NM, July 2018). The models used by Sandia in these studies employ realistic knowledge of RDD designs, particle distribution, and methods of dispersal. Sandia has also had access to infrastructure modeling to assess the effects of an RDD event on regional infrastructure. However, in the 2018 study, a complete analysis to the level of rigor of the 2017 study was not possible, given the time and resource constraints. When it was possible, the results of the 2017 study were scaled to account for the smaller area contaminated, and in areas where the 2017 study indicated negligible effects, it was assumed that the effects of the category 3 device would be even smaller. The studies modeled two scenarios, but did not quantify the range of possible scenarios or the uncertainty in the estimates. Nonetheless, these models demonstrate the consequences could be substantial from an RDD.

federal government standards assumed in the study. The expert said that locals will always want to clean up to a higher standard than federal government guidance recommends, largely due to a desire to protect economic assets such as trade, brand, and image.

In addition to socioeconomic concerns, experts who attended our meeting generally noted that an assessment of the consequence of an RDD should consider fatalities resulting from the evacuation of homes and business. For example, one expert from our meeting said that there were few deaths from radiation during the incident at the Fukushima nuclear complex in 2011, but there were many deaths from the evacuation. Another expert agreed and said that there is evidence from Chernobyl and Fukushima linking health effects to evacuations and that, therefore, fatalities from evacuations should be included on the list of consequences from an RDD. A third expert said that panic cannot be underestimated in the event of an RDD, and the consequences of evacuation and relocation would exceed prompt fatalities and deterministic health effects. Finally, one expert said that many people outside of the evacuation area will also choose to relocate after an RDD rather than wait for direction from the government, which could increase the number of evacuees and lead to additional fatalities.

The 2017 and 2018 Sandia studies support these concerns, estimating that these evacuations could cause hundreds to thousands of deaths and that fatalities during evacuations are similar for RDDs using category 1 and category 3 quantities of the same material. Specifically, the 2017 Sandia study examined the number of fatalities that occurred during the evacuation from the disaster at the Fukushima nuclear complex. Using that event as a baseline, the Sandia study estimated that approximately 1,500 people could die from the evacuation associated with the detonation of an RDD containing a category 1 quantity of radioactive material in New York City.[46] The 2018 Sandia study of a detonation of an RDD containing a category 3 quantity of radioactive material estimated that approximately 800 people could die from the evacuation.

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[46] This estimate is calculated using information observed after the Fukushima nuclear disaster. The estimate takes into account that vulnerable populations are the most likely to be affected by an evacuation, as opposed to people who could be killed in fatal traffic accidents. This study did not quantify the range of possible scenarios or the uncertainty in the estimates. Nonetheless, this model demonstrates the consequences could be substantial from an RDD.

NRC does not consider socioeconomic consequences or fatalities from evacuations when assessing the consequence of an RDD. Agency officials told us that, under the authority of the Atomic Energy Act, NRC staff has discretion to consider other criteria, including socioeconomic effects, if so directed by the Commission. However, NRC staff told us that they do not currently consider socioeconomic consequences as criteria because they have been specifically directed not to do so by the Commission. In discussions with agency officials, it is unclear why the Commission has directed the NRC staff not to consider other criteria for evaluating the impact of an RDD. NRC's own guidance states that RDDs would cause few deaths from radiation but result in significant socioeconomic impacts. Specifically, NRC guidance issued in May 2014 states: "RDDs are considered weapons of mass disruption; few deaths would occur due to the radioactive nature of the event; however, significant social and socioeconomic impacts could result from public panic, decontamination costs, and the denial of access to infrastructure and property for extended periods of time."[47] NRC's decision to not consider other criteria has limited its assessments of risk presented by the use of radioactive material in an RDD. By considering socioeconomic impacts and fatalities resulting from evacuations in its criteria, NRC would have better assurance that it was considering the more likely and more significant consequences of an RDD when establishing its security requirements for this material.

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[47] Nuclear Regulatory Commission, *Physical Security Best Practices for the Protection of Risk-Significant Radioactive Materials*, NUREG-2166 (Washington, D.C.: May 2014).

NRC's 2016 Report Does Not Fully Reflect the Risks of High-Risk Category 3 Material, Collocation of Americium-241, and Protection against Insider Threats

In 2016, NRC evaluated the effectiveness of Part 37, as required by Public Law 113-235, and concluded that the rule is effective for ensuring category 1 and 2 radioactive materials are secure from theft or diversion. However, experts who attended our meeting stated, and recent studies support, that if category 3 quantities of radioactive materials were used in an RDD, the consequences could be comparable to a category 1 or 2 quantity of the same material, which are protected from theft by additional security measures.[48] In addition, experts who participated in our meeting generally said that NRC's current requirements permit collocation at the same facility of multiple category 3 quantities of americium-241 that in total reach or surpass the threshold for a category 2 quantity without the enhanced security required for category 1 and 2 materials. Furthermore, experts generally agreed that there are security weaknesses in the current trustworthiness and reliability process to protect against an insider threat.

NRC's 2016 Evaluation of Part 37 Determined That Current Security Requirements are Adequate for Category 1 and 2 Radioactive Materials

In December 2016, NRC issued a report evaluating the effectiveness of Part 37, as required by Public Law 113-235.[49] NRC's evaluation included an analysis of events and inspection findings related to the security of category 1 and 2 materials, including an analysis of 189 violations issued to NRC State licensees from March 2014 through March 2016. The report found that almost all of the violations were related to conducting background investigations, controlling access to radioactive material, and physical security measures. The violations mainly occurred when licensees had not yet implemented Part 37 or failed to fully document how

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[48] This section reflects comments that experts in radiological security provided at the meeting we convened at the National Academy of Sciences regarding the reasons various radionuclides should be considered high risk, the reasons these radionuclides should not be considered high risk, and on balance, whether these radionuclides should be considered high risk. This section also reflects comments that these experts provided regarding the potential vulnerabilities of radioactive materials and their potential consequences if used in an RDD. In that meeting, we presented four scenarios of different types of radiological materials stored under particular circumstances. For these scenarios, we asked experts about the primary vulnerabilities of these materials in terms of access, monitoring and detection and response, and given the consequences and vulnerabilities, whether the Part 37 security requirements were sufficient. Please see appendix II for additional details on our methodology.

[49] NRC's evaluations included the NRC states: Alaska, Connecticut, Delaware, Hawaii, Idaho, Indiana, Michigan, Missouri, Montana, South Dakota, Vermont, West Virginia, as well as the District of Columbia, Puerto Rico, and the U.S. Virgin Islands.

their security program complied with Part 37. The report noted that there were no Severity Level I or Severity Level II violations.[50]

The NRC report looked at the theft of six category 2 quantities of radioactive material since the introduction of the Increased Controls security requirements in 2003 and concluded that carelessness or human error, rather than any gaps in the requirements of Part 37, contributed to the thefts.[51] As we reported in 2014, the thefts included industrial radiography cameras with category 2 quantities of iridium-192 sources stolen from radiography trucks parked outside a company facility, in hotel parking lots, and at a gas station.[52] NRC concluded that in all the events, carelessness or human error contributed to the thefts and had the licensees followed existing regulatory requirements, the thefts could have been prevented.

NRC's 2016 report concluded that better outreach and communication would help improve compliance with Part 37. NRC's report also documents NRC staff's determination that the requirements in Part 37 are effective in preventing the theft or diversion of category 1 and 2 quantities of radioactive material. NRC determined that potential rule clarifications and guidance initiatives could help to enhance the clarity and effectiveness of the rule, ensure better understanding of security expectations, and allow for more complete and adequate implementation. NRC's overall assessment is that Part 37 provides reasonable assurance for the security of category 1 and 2 quantities of radioactive material by protecting the material from theft or diversion.

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[50] Severity level designations reflect different degrees of significance and include, from highest to lowest, Severity Levels I, II, III, and IV, and minor violations.

[51] This time frame coincides with when the Increased Control Orders went into effect.

[52] GAO-14-293. NRC's report did not look into the two cases we found in which individuals impersonated safety and security inspectors at remote worksites in 2010.

NRC's 2016 Evaluation Did Not Consider the Security of Category 3 Material That Experts Consider High Risk

In conducting its evaluation, NRC examined past security incidents and inspection reports, but its report did not review the security requirements for category 3, 4, or 5 quantities of radioactive material because NRC does not consider these categories to be a significant risk.[53] NRC chose to define high-risk radioactive material as only category 1 and 2.[54] NRC does not further elaborate why it took this approach.

NRC's reliance on prompt fatalities and deterministic health effects and its exclusion of socioeconomic consequences and deaths from evacuations as criteria for determining the consequences of an RDD, as discussed earlier, has resulted in security requirements that do not include all high-risk quantities of some radioactive materials. Experts who participated in our meeting generally agreed that some category 3 quantities of radioactive material should be considered high risk based on their potential consequences if used in an RDD. For example, one international expert pointed out that IAEA guidance includes security measures for category 3 quantities of material and expressed surprise that U.S. guidelines do not include additional security measures for category 3 quantities. Another expert suggested that NRC include category 3 quantities of radioactive material in the National Source Tracking System, which would allow for license verification during purchases. In this expert's opinion, the main vulnerability for category 3 quantities of radioactive material is that they can be purchased with a license that has not been verified as legitimate by the NRC or an agreement state.

The experts also generally said that some category 3 radioactive material should be considered high risk and should be subject to additional security measures. For example, one expert suggested that some types of category 3 radioactive material may need additional oversight.

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[53] NRC does not require additional security measures for category 3, 4, or 5 quantities of material beyond existing health and safety requirements. Under NRC regulations 10 C.F.R. § 20.1801 and 10 C.F.R. § 20.1802, a licensee is required to secure from unauthorized removal or access licensed materials that are stored in controlled or unrestricted areas. Furthermore, licensees are required to control and maintain constant surveillance of licensed material that is in a controlled or unrestricted area and that is not in storage.

[54] In its report, NRC noted that the legislation uses the term "high risk," but the Radiation Source Protection and Security Task Force and the NRC use the term "risk-significant." NRC defines risk-significant quantities of radioactive material as those meeting the thresholds for category 1 and 2 as included both in the IAEA Code of Conduct on the Safety and Security of Radioactive Sources and in Part 37.

However, this expert said that NRC should consider a more nuanced approach to increasing the security for some, but not all, quantities of category 3 radioactive material. Another expert agreed and said that the ability to disperse material is a primary factor in determining if something is high risk. For this reason, this expert said, category 3 quantities of some types of radioactive material should be considered high risk, and there may be need for an additional category of materials that falls below category 2 but that includes the most dangerous high-risk materials in category 3 quantities. An expert who attended our meeting stated that certain radioactive materials pose a unique decontamination challenge because those materials bind to materials like asphalt and concrete, making decontamination difficult and expensive. One expert said that the consequences listed in the 2018 Sandia report were enough to justify requiring additional security measures for category 3 quantities of certain radioactive materials. As shown in table 1, the 2018 Sandia study found that a category 3 quantity of radioactive material could result in socioeconomic consequences and fatalities from evacuations similar to an RDD with a category 1 quantity of radioactive material.

Table 1: Comparison of Consequences of an RDD using Category 1 and Category 3 Quantities of Radioactive Material

Activities	Potential Consequences	
	Category 1 RDD	Category 3 RDD
Socioeconomic impact on the U.S. Gross Domestic Product	~$30 billion	~$24 billion
Evacuations	~195,000	~102,000
Fatalities from evacuations	~1,500	~800
Prompt fatalities from radiation	0	0
Screenings for radiation	~195,000	~102,000
Relocations	~14,000	~12,000

Source: Sandia National Laboratories. | GAO-19-468

Note: The models used by Sandia National Laboratories in these studies employ realistic knowledge of radiological dispersal device (RDD) designs, particle distribution, and methods of dispersal. Sandia has also had access to infrastructure modeling to assess the effects of an RDD event on regional infrastructure. However, the complete analysis of the 2018 study was not completed to the level of rigor of the 2017 study, given the time and resource constraints. The studies modeled two scenarios, but did not quantify the range of possible outcomes or the uncertainty in the estimates. Nonetheless, these models demonstrate that consequences could be substantial from an RDD.

The experts also generally said that there could be long-term socioeconomic consequences unique to the risk posed by an RDD that used a category 3 quantity of radioactive material, and certain radioactive materials in smaller quantities should be considered high risk. As we described earlier, NRC reported in a 2017 Threat, Consequence, and

Vulnerability Assessment that even if several hundred category 3 quantities of a certain radioactive material were used in an RDD, it would not create an RDD of consequence. In our discussions with NRC staff, they expanded on this point and stated that there may not be enough of this material in the United States to build an RDD of consequence. However, new research from Sandia found that a category 3 quantity of the same material could trigger an evacuation and result in significant socioeconomic consequences.[55]

According to an expert from the regulatory community, while the Commission has considered requiring additional security measures for category 3 quantities of material, NRC staff recommended against doing so because the costs of providing additional security would outweigh the benefits. For example, one expert who attended our meeting said that the choice is between the difference in costs of absolute security and adequate security, and the cost/benefit analysis does not support including category 3 quantities of radioactive materials in Part 37. The expert pointed out that there have been relatively few thefts of category 3 sources in the United States and suggested that providing additional security should be weighed against the low likelihood that the radioactive materials would be stolen.

While there were differing views in our expert meeting between the regulatory community and other experts, the experts generally agreed, and the Sandia studies support, that the consequences of category 3 quantities of certain types of material could be significant. By requiring additional security measures for these high-risk quantities of category 3 material, and assessing whether other category 3 radioactive materials should also be safeguarded with additional security measures, NRC could have better assurance that its requirements are sufficient to help ensure all high-risk radioactive material is protected from theft and use in an RDD.

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[55] Potter, Charles “Gus,” PhD, CHP, Sandia National Laboratories, “Current Research in Particulate Resuspension” (Albuquerque, NM: September 5, 2018). The author of the study noted that there have been a number of studies on the power to contaminate of a certain radioactive material, and over time, those amounts have changed as research has advanced and could change again in the future.

NRC's 2016 Report Does Not Fully Address Weaknesses in Part 37's Regulation of the Collocation of Americium-241 and How NRC Protects against an Insider Threat

NRC's 2016 report looked at the risks posed by the collocation of category 3 quantities of material and insider threats. NRC concluded that rule clarifications and additional guidance could help enhance clarity and effectives of the rule, but its report does not fully address how these risks should be managed. For example, experts who participated in our meeting generally agreed that weaknesses continue to exist in how Part 37 regulates the collocation of multiple category 3 quantities of americium-241 at a single facility. Specifically, NRC requirements permit collocation of multiple category 3 quantities of material that in total reach a category 1 or 2 quantity of material, without applying Part 37. Experts told us that well logging companies, which use americium-241 to inspect wells for oil and natural gas, are storing multiple category 3 quantities, each just below the threshold for category 2, of americium-241 at the same facility; thus, the total quantity does not trigger additional security requirements under Part 37. Figure 3 shows a well logging storage facility containing multiple category 3 quantities of americium-241.

Figure 3: Well Logging Storage Facility with Multiple Containers for Storing Radioactive Material

Source: National Nuclear Security Administration. | GAO-19-468

Note: The multiple in-ground containers store the radioactive materials, which in some cases can contain americium-241 of individual quantities below an aggregate quantity that would trigger Part 37 requirements for increased security measures.

Experts at our meeting generally said that collocation of multiple quantities of category 3 americium-241 at well logging facilities creates specific security weaknesses that should be addressed. For example, one expert who attended our meeting from the regulatory community said that NRC has no formal definition for collocation, but Part 37 considers it acceptable to store multiple category 3 quantities of radioactive material in separate, locked containers that, together, add up to a category 2 quantity. Another expert pointed out that when NNSA evaluates threats to materials, it totals up the quantity of materials located at the same facility to determine the total amount of material at risk. A third expert noted that licensees are required to inventory category 3 quantities of material only twice per year. Furthermore, the experts pointed out that these types of facilities are not subject to stricter security requirements, and therefore, do not undertake trustworthiness and reliability evaluations for their employees with unescorted access to radioactive material. By requiring that all licensees implement additional security measures when they collocate multiple quantities of category 3 americium-241—that in total reach a category 1 or 2 quantity—at a single facility, NRC could have better assurance that the material is protected from theft and use in an RDD.

Furthermore, experts who participated in our meeting generally agreed that there continue to be security weaknesses in the current trustworthiness and reliability process for securing radioactive material from theft and use in an RDD. For example, one expert from the licensee community who attended our meeting said that NRC's Part 37 does not go far enough in ensuring the trustworthiness and reliability of individuals given unescorted access. Specifically, the expert said that, based on the Part 37 requirements, licensees make all trustworthiness and reliability determinations for granting unescorted access to employees, which leads to inconsistencies across licensees. The experts generally said that NRC should give licensees more guidance on acceptable criteria for granting unescorted access, which is consistent with recommendations included in past GAO reports.[56] NRC is currently in the process of making revisions to its trustworthiness and reliability guidance.

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[56] GAO, *Nuclear Nonproliferation: Additional Actions Needed to Improve Security of Radiological Sources at U.S. Medical Facilities*, GAO-12-925 (Washington, D.C.: Sept. 10, 2002) and GAO, *Nuclear Nonproliferation: Additional Actions Needed to Increase the Security of U.S. Industrial Radiological Sources*, GAO-14-293 (Washington, D.C.: June 6, 2014).

Experts who attended our meeting said that licensees face challenges in making trustworthiness and reliability determinations, including the fear of being sued if they deny employment to an individual with a criminal record, difficulty conducting background investigations for foreign nationals, and the potential for individuals to be radicalized more quickly than the current trustworthiness and reliability process protects against. One expert from the regulatory community who attended our meeting said that trustworthiness and reliability decisions are a “judgment call,” and when an applicant has a criminal record or has committed a felony, a company may not want to give them unescorted access to radioactive material. However, the expert added that denial of unescorted access without backup from NRC guidance may leave the company open to lawsuits. In addition, another expert who attended our meeting said institutions that often employ foreign nationals as researchers, such as hospitals, struggle with verifying limited background information for these individuals. Finally, an expert who attended our meeting said that perception of trustworthiness and reliability has recently changed, and there is now greater concern that people can be radicalized quickly, rendering background investigations insufficient to identify potential issues with an employee’s trustworthiness and reliability during their employment. The expert told the group that there is evidence that individuals can be radicalized in a matter of months. The expert said that current trustworthiness and reliability procedures should take into account that people’s beliefs can change rapidly.

Conclusions

Radioactive material is used in thousands of locations throughout the United States for medical, industrial, and research purposes. On several occasions over the past 20 years, NRC has examined and revised the security requirements for these materials in order to prevent terrorists from acquiring radioactive material and constructing an RDD, or “dirty bomb.” When assessing the risk posed by an RDD, NRC has repeatedly looked at different criteria for measuring consequences and chose to base its decisions primarily on preventing prompt fatalities and deterministic health effects from radiation. However, the experts who participated in our meeting generally agreed, and Sandia studies support, that socioeconomic effects and fatalities from subsequent evacuations are relevant criteria for assessing the consequences of an RDD. NRC’s decision to not consider other criteria to assess the consequence of an RDD has resulted in security requirements that do not address the full risks presented by the danger that category 3 quantities of some radioactive material could be used in an RDD to cause significant socioeconomic consequences comparable to what could be caused by category 2 or category 1 quantities of material. By considering socioeconomic impacts and fatalities resulting from evacuations in its criteria, NRC would have better assurance that it was considering more likely and more significant consequences of an RDD when establishing its security requirements for this material.

Furthermore, Part 37 requires enhanced security measures for categories 1 and 2 quantities of radioactive material and does not require additional security for category 3, 4, and 5 quantities of material beyond existing safety requirements. Although NRC chose to limit its 2016 evaluation of Part 37 to only category 1 and 2 quantities of material, experts who participated in our meeting generally said that they consider certain category 3 quantities of radioactive material high risk based on their potential consequences if used in an RDD, and data from recent studies support this determination. By requiring additional security measures for these high-risk quantities of category 3 material, and assessing whether other category 3 radioactive materials should be safeguarded with additional security measures, NRC can have better assurance that its requirements are sufficient to help ensure all high-risk radioactive material are protected from theft and use in an RDD.

In addition, NRC's 2016 report looked at the risk posed by the collocation of category 3 quantities of material and concluded that rule clarifications and additional guidance could help enhance the clarity and effectiveness of the rule. However, the report does not fully address how this risk should be resolved. Current NRC security requirements permit the collocation of multiple category 3 quantities of material that in total reach a category 2 quantity of material or higher, without triggering additional security requirements under Part 37. By requiring that all licensees implement additional security measures when they collocate multiple quantities of category 3 americium-241—that in total reach a category 1 or 2 quantity—at a single facility, NRC could have better assurance that the material is protected from theft and use in an RDD.

Recommendations for Executive Action

We are making the following three recommendations to the Nuclear Regulatory Commission:

- The Chairman of NRC should direct NRC staff to consider socioeconomic consequences and fatalities from evacuations in the criteria for determining what security measures should be required for radioactive materials that could be used in an RDD. (Recommendation 1)

- The Chairman of NRC should require additional security measures for high-risk quantities of certain category 3 radioactive material, and assess whether other category 3 materials should also be safeguarded with additional security measures. (Recommendation 2)
- The Chairman of NRC should require all licensees to implement additional security measures when they have multiple quantities of category 3 americium-241 at a single facility that in total reach a category 1 or 2 quantity of material. (Recommendation 3)

Agency Comments

We provided a draft of this report to the Chairman of NRC, the Administrator of NNSA, the Secretary of the Department of Homeland Security, and the Attorney General of the United States. NRC provided written comments on the draft report, which are presented in appendix III. In addition, NRC provided technical comments, which we incorporated as appropriate. NNSA, DHS, and FBI did not provide written comments.

NRC disagreed with two of our recommendations and neither agreed nor disagreed with an additional recommendation. Specifically, it disagreed with our recommendations that it (1) consider socioeconomic consequences and fatalities from evacuations when determining security measures for radioactive materials; and (2) require licensees to implement additional security measures when they have multiple quantities of category 3 americium-241 at a single facility that in total reach a category 1 or 2 quantity. NRC stated that it is considering an additional recommendation that it require additional security measures for high-risk quantities of category 3 materials.

Regarding the first recommendation with which NRC disagreed, the agency stated that its current regulatory requirements provide for the safe and secure use of radioactive materials, and that we only focused on potential consequences of an RDD without consideration of the two other elements of risk—threat and vulnerability. We disagree. NRC agrees that a general threat exists, and this report, in combination with our previous reports, demonstrate that there are vulnerabilities in current NRC security requirements and that the potential consequences of misusing these materials could be significant. Furthermore, the report discusses new evidence related to the consequence of an RDD that NRC has not yet considered. For the second recommendation with which it disagreed, NRC stated that it has already considered the issue of aggregation of radioactive material and has taken or is in the process of taking actions to clarify relevant guidance and procedures. Again, we disagree. We acknowledge that NRC is taking action to better educate licensees on how to comply with requirements related to aggregation. However, these actions do not address the issue of licensees taking advantage of NRC's security requirements which permit the storing of multiple category 3 quantities that are just below the threshold for category 2 at the same facility. Finally, for the NRC recommendation to consider additional security measures for high-risk quantities of category 3 materials, the agency said that it has been considering our recommendation in connection with its response to the recommendations in GAO-16-330. However, after we issued GAO-16-330, NRC staff subsequently recommended that the NRC Commission not implement the recommendations from that report.

NRC stated that our report and recommendations lack important context in that we did not consider all aspects of risk—threat, vulnerability, and consequences. We disagree. First, as the report states, NRC agrees that a general threat exists for the theft and misuse of radiological materials. Second, the report also states that we have addressed vulnerability in several past GAO reports that provide examples of how the controls that NRC and others have put in place to prevent the theft or misuse of these materials are not always implemented correctly. In fact, we found gaps in these controls each time we reviewed the security of radioactive materials. These gaps in controls create vulnerabilities. Having discussed threat and vulnerability, this report adds important new information concerning the consequences of an RDD. In this regard, both the Sandia studies and the results from our National Academy of Sciences expert meeting show that prompt fatalities from radiation are unlikely to occur if an RDD is detonated, while the same event could result in tens of billions of dollars in economic damage and potentially hundreds to thousands of deaths from evacuations.

NRC also stated that our evidence was insufficient for recommending regulatory and policy changes. Specifically, they said that the Sandia studies (1) were based on scenarios that were not probable, (2) did not credit existing protective measures to prevent an RDD, and (3) were not subjected to a formal review and endorsement process. In addition, they said that the views expressed by experts who attended our National Academy of Sciences meeting resulted in conclusions that were not fully supported. We disagree with these characterizations of the studies and our expert meeting. Specifically, the Sandia studies did not attempt to assess existing security measures for radioactive material or the probability or likelihood of an RDD. These Sandia studies examined the consequences of an RDD and represent the most recent research on RDD consequences from an independent and reliable source. In addition, NRC's claim that the Sandia studies were conducted without a formal review and endorsement process is misleading. Specifically, according to NNSA officials, Sandia and NNSA officials met with officials from NRC, DHS, and EPA, among others, to discuss and gather input on the assumptions to be used in the 2017 Sandia study. During this meeting, according to NNSA officials, NRC staff provided input on key assumptions and subsequently provided data to help support the Sandia study. In addition, NNSA and Sandia briefed their interagency partners, including NRC, about the findings in the study before publishing and received generally positive feedback on their results. Furthermore, we partnered with the National Academies to identify and select a broad range of experts in the field of radioactive material security, including federal agency and agreement state officials; academics; representatives of nonprofit organizations, licensees, and industry; international regulators; and national laboratory specialists. For additional information on how we developed, held, and analyzed data from our National Academy of Sciences expert meeting, please refer to appendix 2.

NRC's comments also state that GAO does not account for the work of the 2014 Radiation Source Protection and Security Task Force (the Task Force), which considered economic consequences related to an RDD. However, as noted in our report, NRC's response to the Task Force's recommendations said that NRC staff would need additional direction from the Commission to consider examining alternative consequences. In addition, in 2014, NRC staff recommended that NRC not consider changing the policy to include consideration of socioeconomic consequences to the Commission, reiterating the staff's view that Part 37 provides adequate security protection against a significant RDD. Today, NRC staff still does not have direction from the Commission to consider socioeconomic effects when setting security requirements. We think that needs to change in order for NRC to conduct a complete analysis of the consequences of an RDD.

Finally, NRC stated that a significant gap related to the security of category 3 sources has not been identified. We disagree. As noted in the report, requirements for the security of category 3 quantities of radioactive materials are significantly less stringent than those required for category 1 and 2 quantities of material. Nevertheless, our report shows that the use of category 3 quantities of certain radioactive materials in an RDD may have comparable socioeconomic consequences. Furthermore, previous GAO reports have repeatedly shown that gaps exist related to the security of category 3 and higher radioactive material.

We are sending copies of this report to the appropriate congressional committees, the Chairman of the U.S. Nuclear Regulatory Commission, the Secretary of Energy, the Secretary of Homeland Security, the Administrator of the Environmental Protection Agency, and the Attorney General of the United States, and other interested parties. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or trimbled@gao.gov. Contact points for our offices of Congressional Relations and Public Affairs are on the last page of this report. GAO staff who made key contributions to this report are listed in appendix IV.

David C. Trimble

David C. Trimble
Director, Natural Resources and Environment

Appendix I: List of Experts

Tom Bielefeld, nuclear security researcher and independent consultant, member of the Fissile Materials Working Group and the World Institute for Nuclear Security

Chris Boyd, Former Assistant Commissioner for New York City Department of Health and Mental Hygiene and Agreement State official

Dan Collins, Director of the Division of Materials Safety, Security, State and Tribal Programs in the U.S. Nuclear Regulatory Commission's (NRC) Office of Nuclear Material Safety and Safeguards

Leonard "Len" Connell, senior technical consultant on radiological and nuclear terrorism for the National Nuclear Security Administration's (NNSA), Sandia National Laboratories, the Nuclear Threat Initiative, and the Stanford Center for International Security and Cooperation

Cristen Ford, Domestic Program Deputy Director, NNSA's Office of Radiological Security

John Garrick, University of California Los Angeles, Henry Samueli School of Engineering and Applied Science, founder of the B. John Garrick Institute of the Risk Sciences, UCLA

Ioanna Iliopuos, Senior Consultant, the National Threat Initiative Radiological Security Program, previously Director of the Office of North and South American Threat Reduction within NNSA's Global Threat Reduction Initiative

Pierre Legoux, Manager of the operational program at the World Institute for Nuclear Security, previously Physical Protection Specialist at the International Atomic Energy Agency's (IAEA) Office of Nuclear Security

William Lorenzen, Manager of Research Laboratory Support Office & Radiation Safety Officer, Children's Hospital Boston

Jennifer Opila, Chair of the Organization of Agreement States, Manager of the Radiation Program, Colorado Department of Public Health and Environment

Craig Piercy, Washington Representative for the American Nuclear Society, Head of the Washington office the Bose Public Affairs Group

Miles Pomper, Senior fellow, Middlebury Institute of International Studies, James Martin Center for Nonproliferation Studies and Chair of the Fissile Materials Working Group

Richard “Dick” Rosano, Excel Corporation, current permanent member of the U.N. IAEA task force on nuclear security, formerly served as the senior nuclear advisor to the NRC Executive Director for Operations and three NRC Chairmen

Adam Rose, Research Professor and Economist, University of Southern California Sol Price School of Public Policy, faculty affiliate of the University of Southern California’s Center for Risk and Economic Analysis of Terrorism Events

Daniel Schultheisz, Associate Director of the Center for Waste Management and Regulations in Environmental Protection Agency’s Radiation Protection Division

Warren Stern, Senior advisor, Brookhaven National Laboratory’s Nonproliferation and National Security Department, former Director of the Department of Homeland Security’s Domestic Nuclear Detection Office

Vanessa Vargas, Principal Member of the Technical Staff, and Lead Economist in the Resilience and Regulatory Effects group, Sandia National Laboratories

Peter Zimmerman, Emeritus Professor of Science and Security at King’s College London, former Chief Scientist of the Senate Foreign Relations Committee, retired nuclear physicist

Appendix II: Scope and Methodology

We focused our review primarily on the Nuclear Regulatory Commission (NRC) because it is the principal federal agency with responsibility for licensing the commercial use of and regulating the security of radioactive materials in the United States. Additionally, Public Law 113-235 specifically directs us to review NRC's security requirements for radioactive material. We also interviewed officials at various agencies that play a role in radioactive material security, including the National Nuclear Security Administration (NNSA), the Department of Homeland Security (DHS), the Environmental Protection Agency (EPA), and the Federal Bureau of Investigation (FBI). We interviewed officials at NNSA because NNSA's Office of Radiological Security provides upgrades and enhancements to NRC licensees and removes and disposes of disused radioactive material. We also spoke to DHS officials because DHS is the primary federal agency for implementing domestic nuclear detection efforts for a managed and coordinated response to radioactive and nuclear threats. Additionally, we interviewed officials at EPA, because the agency developed the Protective Action Guide (PAG) manual, which contains radiation dose guidelines that would trigger public safety measures. Finally, we interviewed the FBI, which offered us information on the potential threat related to radioactive material security. In addition to federal agencies, we were contacted by and spoke to a working group that represents the commercial radioactive source industry and received a briefing from a company, which is also a member of the working group that utilizes large panoramic irradiators.

We received a series of risk briefings from federal agencies to collect information on current risks related to radioactive material security. NRC officials provided us with information about how the agency evaluates risks associated with radioactive material, including the threat, vulnerability, and consequence of an adversary acquiring and using radioactive material in a radioactive dispersal device (RDD). DHS officials provided us with a risk briefing on current threats to radioactive material and potential consequences of an RDD attack. Specifically, those officials briefed us on historical terrorist interest in using radioactive materials in attacks. NNSA officials and Sandia National Laboratory experts in radioactive security and consequence modeling briefed us on potential economic consequences from an RDD, which they based on an economic impact study completed by Sandia in 2018. Finally, FBI officials gave us a threat briefing focused on current radioactive material security threats, including interest by adversaries in conducting an RDD attack. These briefings were held at a classified level.

In order to fulfill the Public Law 113-235 requirement to work with an independent group of experts, we partnered with the National Academies of Sciences to convene a group of experts on radioactive material security on July 26 and 27, 2018. We determined that this method offered the best means of gathering a balanced group of leading experts in the field of radioactive security to discuss issues in a moderated setting. In addition, this method allowed us to implement a structured and systematic approach when gathering evidence. Specifically, our methodology for the meeting included selecting a broad range of experts to participate in the meeting, administering a written questionnaire to the experts before the meeting, designing specific scenarios used during the moderated discussion, and performing a thematic analysis upon completion of the meeting.

To describe how NRC assesses risk when establishing security requirements for high-risk radioactive materials and how it chose to primarily consider prompt fatalities as criteria for measuring consequences of an RDD, we reviewed NRC documents addressing how NRC evaluates an RDD, NRC's study evaluating the effectiveness of Part 37 in response to Public Law 113-235, and NRC's analysis of the risks posed by high-risk radioactive materials. Specifically, we reviewed NRC Commission Papers and NRC responses to actions taken by the Radiation Source Protection and Security Task Force. We also conducted interviews with agency officials at NRC, NNSA, DHS, EPA, and FBI, as well as academics, agreement state officials, and security managers from industry about the risks associated with different categories of radioactive materials and how NRC regulates these materials. We selected interviewees based on their expertise, but the results of these interviews are not generalizable.

To examine the extent to which radioactive security experts agreed that NRC's assessment of risk includes all relevant criteria for establishing security requirements, we partnered with the National Academies to identify and select a broad range of experts in the field of radioactive material security, including federal agency and agreement state officials; academics; representatives of nonprofit organizations, licensees, and industry; international regulators; and national laboratory specialists. In choosing the group of 18 experts, we specifically chose individuals with a diversity of backgrounds on topics. This ensured a balanced range of opinions and specific expertise on given topics but did not represent a generalizable sample of experts on a specific topic. For example, some individuals had specific expertise in certain topics and could provide a more insightful perspective than others in the group.

In advance of the meeting, we developed a written questionnaire to obtain the experts' views on the key threats, vulnerabilities and consequences of materials regulated under Part 37 and those not regulated under Part 37. We administered the questionnaire to the experts via email and obtained completed questionnaires from all of them. We analyzed their responses to focus the topics we discussed during our two-day meeting. During the meeting, we introduced the threat of malevolent use of radioactive material, and we asked the experts to focus their discussion the potential consequences of an RDD, the vulnerabilities of radiological materials under current security requirements and whether current security requirements were sufficient given these consequences and vulnerabilities. We asked them to discuss the reasons to account for the consequence in the regulation of radioactive material, the reasons not to account for the consequence, and whether the consequence should be accounted for. In addition, we asked the experts the reasons various radionuclides should be considered high risk, the reasons these radionuclides should not be considered high risk, and on balance, whether these radionuclides should be considered high risk. Our meeting agenda and moderator guide also included detailed scenarios designed to probe issues related to radioactive security and provide clear parameters within which the experts could make observations. In particular, we presented the experts with four scenarios of differing quantities of radioactive material used for particular medical and industrial purposes and stored under particular circumstances. The four scenarios presented different types of radioactive materials stored under particular circumstances. For these scenarios, we asked experts about the primary vulnerabilities of these materials in terms of access, monitoring and detection and response, and given the consequences and vulnerabilities, whether the Part 37 security requirements were sufficient. We based these scenarios on situations we observed during our prior work on the security of radioactive material. For each of these scenarios, we asked experts to assess two key elements of the risk triplet—vulnerability to being used and consequences if used.[1] For example, we included a presentation on threat associated with radioactive materials. Additionally, for each scenario we moderated discussions on scenarios focused on vulnerabilities of category 1 and category 3 radioactive materials or scenarios focused on the consequences of category 1 and category 3 RDDs. Furthermore, a GAO methodologist and a National Academies of

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[1] The risk of an RDD is determined by the function of three components: threat, vulnerability, and consequence. Taken together, the three components make up a "risk triplet."

Sciences official guided discussions, following the structured moderator guide to ensure the discussions addressed all topics. The moderators ensured that experts from all sides had the opportunity to voice their opinions, but time constraints and the nature of an expert meeting may have limited some experts from contributing. Because of this structure, we had no expectation of reaching outright consensus on any specific topic. After the expert meeting, we conducted a structured and systematic thematic analysis of the information gathered to better understand the potential vulnerabilities of radioactive materials to theft and the consequences of an RDD using various radioactive materials. We also worked with GAO methodologists to sort the content in the meeting transcript, identify themes from the sorted information for additional analysis, and evaluate the credibility of expert statements. GAO internally reviewed our analysis for completeness and accuracy and it was found to be sufficient for our purposes. The meeting transcript write-up allowed us to focus on strengths and weaknesses in current security requirements, how the federal government evaluates the consequences of an RDD, what materials should be considered high risk, and whether additional security measures are necessary for these materials. Experts did not speak on every topic, did not have the same level of expertise on every topic, and the meeting format was not designed to quantify experts' comments. Therefore, we do not report the number of the 18 experts who agreed or disagreed with various statements. Instead, through our thematic analysis, we determined that during the expert meeting experts generally made two types of statements on topics with varying degrees of agreement or corroboration, which we refer to as either "strong evidence" or "evidence of varying viewpoints."[2] Two analysts collaborated to determine which of the two categories of evidence applied to particular statements. They reached these decisions based on the criteria listed in table 2 below. Table 2 details these types of statements and how we used the information in this report.

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[2] GAO, *Government Auditing Standards, 2018 Revision*, GAO-18-568G (Washington, D.C.: July 2018). According to government auditing standards, testimonial evidence obtained from an individual who is not biased and has direct knowledge about the area is generally more reliable than testimonial evidence obtained from an individual who is biased or has indirect or partial knowledge about the area.

Table 2: Overview of Use of Evidence from Our Expert Meeting

Types of statements	Characteristics and corroboration (some or all of the following were met by the statement)	How we use statements as evidence
Statements that had strong agreement and support at the expert meeting on a particular topic were considered strong evidence	• multiple experts made this statement • we found the evidence presented by the expert to be sound • evidence was consistent with other evidence that we are aware of, such as past work • experts who made the statement have strong expertise in that area • we did not have experts that fundamentally contradicted the statement with specific evidence	• "Experts generally said…" • "Experts generally told us…" • "Experts generally agreed…"
Statements where both sides are credibly represented by experts on a particular topic were considered evidence of varying viewpoints	• credible experts on a given topic stated one view and others stated another view • we found the evidence presented by both sides to be sound • evidence for both sides was consistent with other evidence that we are aware of, such as past work • experts who made the statement have strong expertise in that area	• "Some experts said X and other experts said Y."

Source: GAO | GAO-19-468

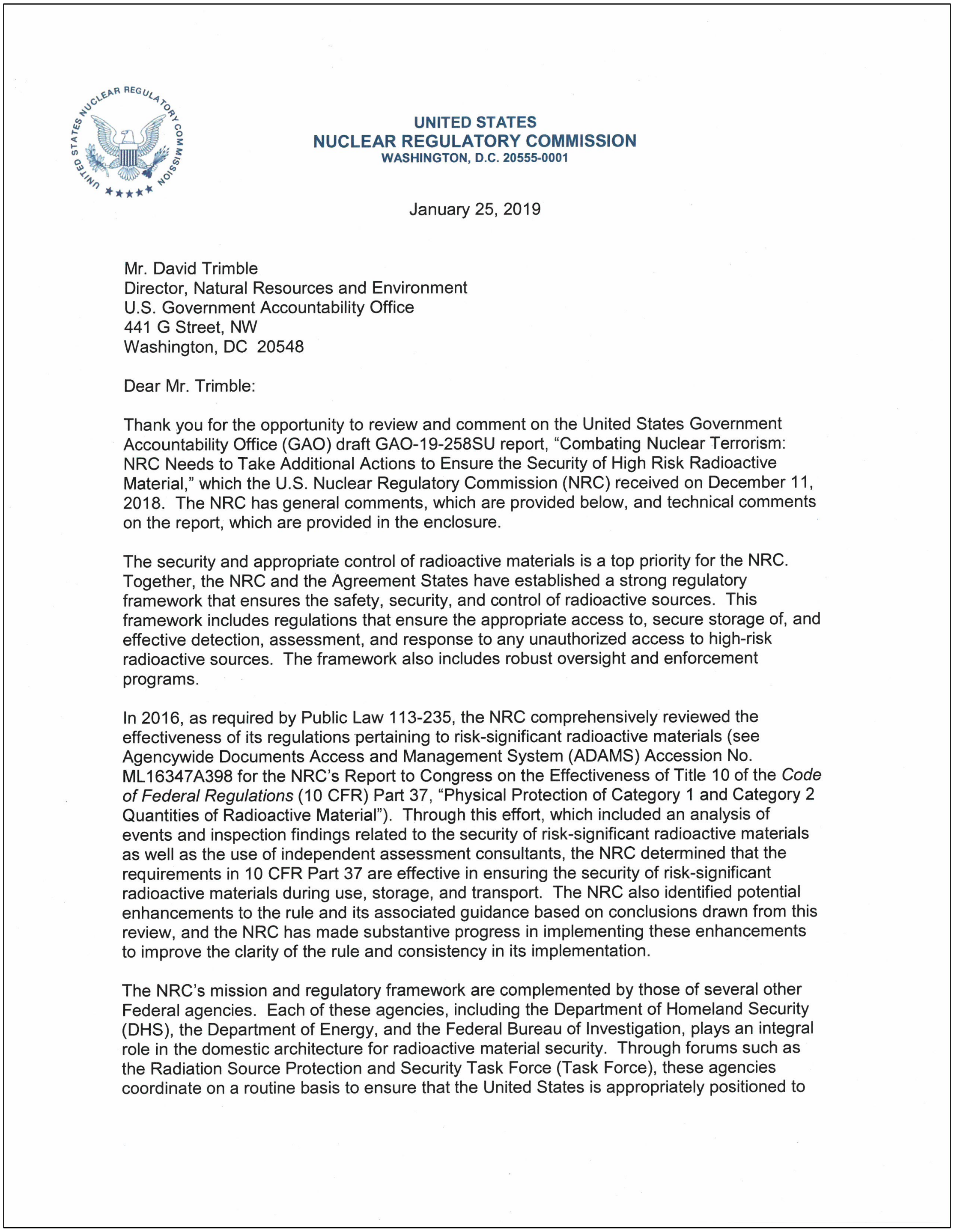
We also interviewed officials and obtained key documents from NRC, NNSA, DHS, FBI, and Sandia on the risk associated with radioactive materials. These documents included Sandia's economic impact studies on the consequences of RDDs with category 1 and category 3 radioactive materials, NRC's evaluation of the effectiveness of Part 37 as required by Public Law 113-235, and various risk briefing materials from NRC, NNSA, and DHS. Interviews with federal government and industry officials also allowed us to examine potential weaknesses in NRC's security requirements that were established to ensure high-risk radioactive material is not acquired by unauthorized individuals for malevolent purposes. During the interviews, we solicited these officials' and industry representatives' opinions on whether NRC's current security requirements are sufficient for ensuring the security of high-risk radioactive material. The interviewees' opinions were non-generalizable. These interviews and our reviews of previous GAO reports allowed us to better understand current security requirements and practices. During the expert meeting we convened with the assistance of the National Academies, we addressed the issue of security measures to prevent the theft of radioactive material, and we conducted a thematic analysis of relevant discussions that included an evaluation of the results. For example, at the expert meeting a moderated discussion explored which criteria NRC should consider when establishing security requirements for radioactive material.

To examine the extent to which certain category 3 radioactive materials are high risk, we reviewed academic research and previous GAO reports on the components of risk, and we traveled to Sandia to interview laboratory officials on the risks associated with various radioactive materials that could be used in an RDD. Additionally, Sandia produced two studies for us describing potential consequences of RDDs. These studies were reviewed by an internal scientist at GAO and determined the study was adequate for our purposes. Both of these studies informed the research engagement findings. Finally, during the expert meeting we convened with the assistance of the National Academies, we addressed whether certain category 3 radioactive materials are high risk. We assessed these sources of information with regard to two key elements of the risk triplet described above—specifically, the vulnerability to being used of various sources of radioactive materials and the consequences if those materials were used. Consistent with the risk triplet, materials that were more vulnerable to being used and that would have a larger consequence if used were interpreted as posing a greater risk than materials that were less vulnerable and would have a smaller consequence. We moderated discussions on the consequences of category 3 RDDs and conducted a thematic analysis of the results.

To examine NRC's 2016 evaluation of its security requirements for high-risk radioactive materials, we reviewed NRC's 2016 evaluation, NRC's 2017 assessment of collocated radioactive material, and previous GAO reports on vulnerabilities in NRC's security procedures for collocation of radioactive materials and the trustworthiness and reliability process. Additionally, we discussed potential weaknesses in NRC's security requirements during meetings with a working group that represents the commercial radioactive source industry and a company that utilizes large panoramic irradiators. Furthermore, during the expert meeting we convened with the assistance of the National Academies, we moderated discussions on potential weaknesses in the current security requirements for high-risk radioactive materials.

We conducted this performance audit from December 2017 to March 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix III: Comments from the Nuclear Regulatory Commission



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

January 25, 2019

Mr. David Trimble
Director, Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

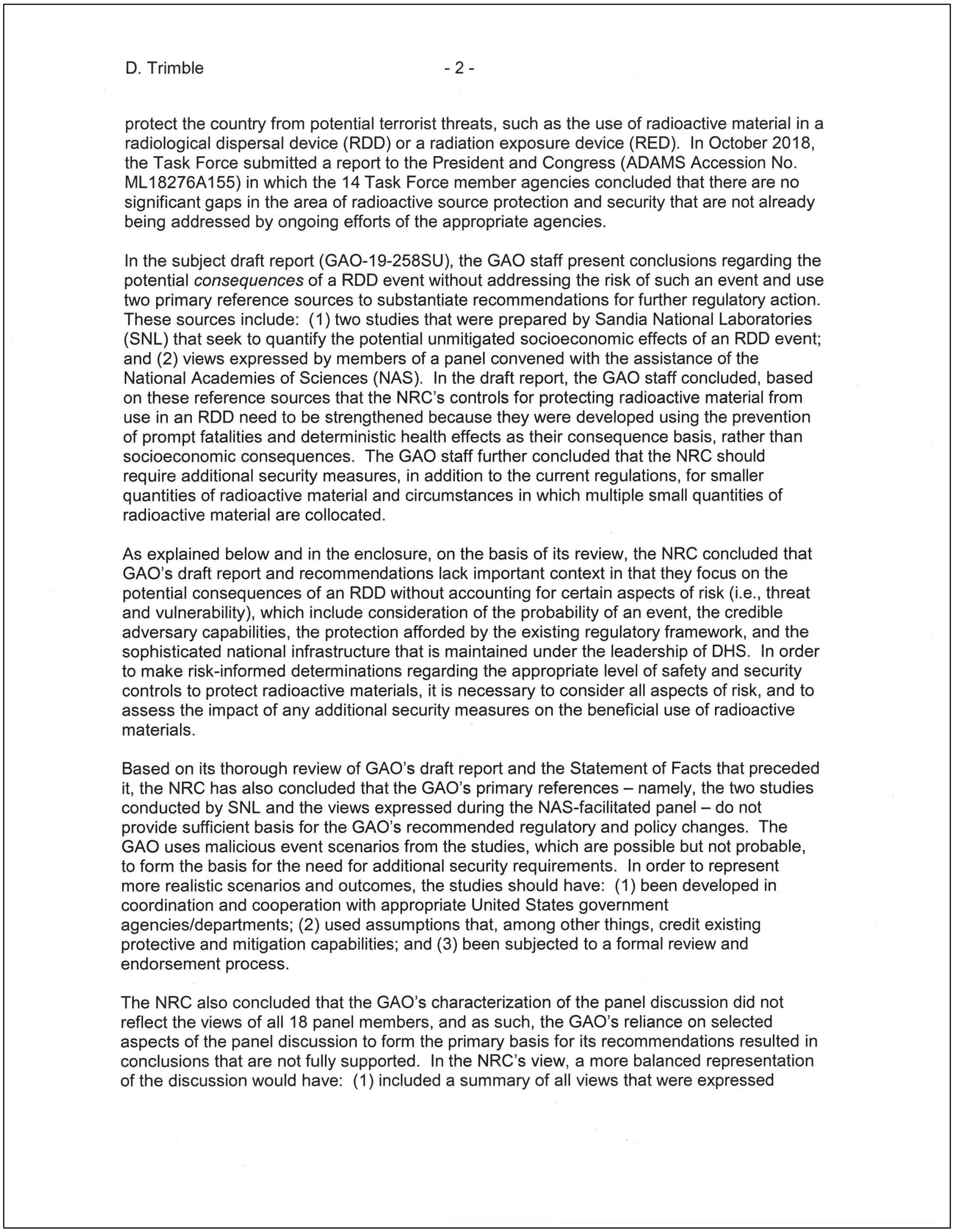
Dear Mr. Trimble:

Thank you for the opportunity to review and comment on the United States Government Accountability Office (GAO) draft GAO-19-258SU report, "Combating Nuclear Terrorism: NRC Needs to Take Additional Actions to Ensure the Security of High Risk Radioactive Material," which the U.S. Nuclear Regulatory Commission (NRC) received on December 11, 2018. The NRC has general comments, which are provided below, and technical comments on the report, which are provided in the enclosure.

The security and appropriate control of radioactive materials is a top priority for the NRC. Together, the NRC and the Agreement States have established a strong regulatory framework that ensures the safety, security, and control of radioactive sources. This framework includes regulations that ensure the appropriate access to, secure storage of, and effective detection, assessment, and response to any unauthorized access to high-risk radioactive sources. The framework also includes robust oversight and enforcement programs.

In 2016, as required by Public Law 113-235, the NRC comprehensively reviewed the effectiveness of its regulations pertaining to risk-significant radioactive materials (see Agencywide Documents Access and Management System (ADAMS) Accession No. ML16347A398 for the NRC's Report to Congress on the Effectiveness of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 37, "Physical Protection of Category 1 and Category 2 Quantities of Radioactive Material"). Through this effort, which included an analysis of events and inspection findings related to the security of risk-significant radioactive materials as well as the use of independent assessment consultants, the NRC determined that the requirements in 10 CFR Part 37 are effective in ensuring the security of risk-significant radioactive materials during use, storage, and transport. The NRC also identified potential enhancements to the rule and its associated guidance based on conclusions drawn from this review, and the NRC has made substantive progress in implementing these enhancements to improve the clarity of the rule and consistency in its implementation.

The NRC's mission and regulatory framework are complemented by those of several other Federal agencies. Each of these agencies, including the Department of Homeland Security (DHS), the Department of Energy, and the Federal Bureau of Investigation, plays an integral role in the domestic architecture for radioactive material security. Through forums such as the Radiation Source Protection and Security Task Force (Task Force), these agencies coordinate on a routine basis to ensure that the United States is appropriately positioned to



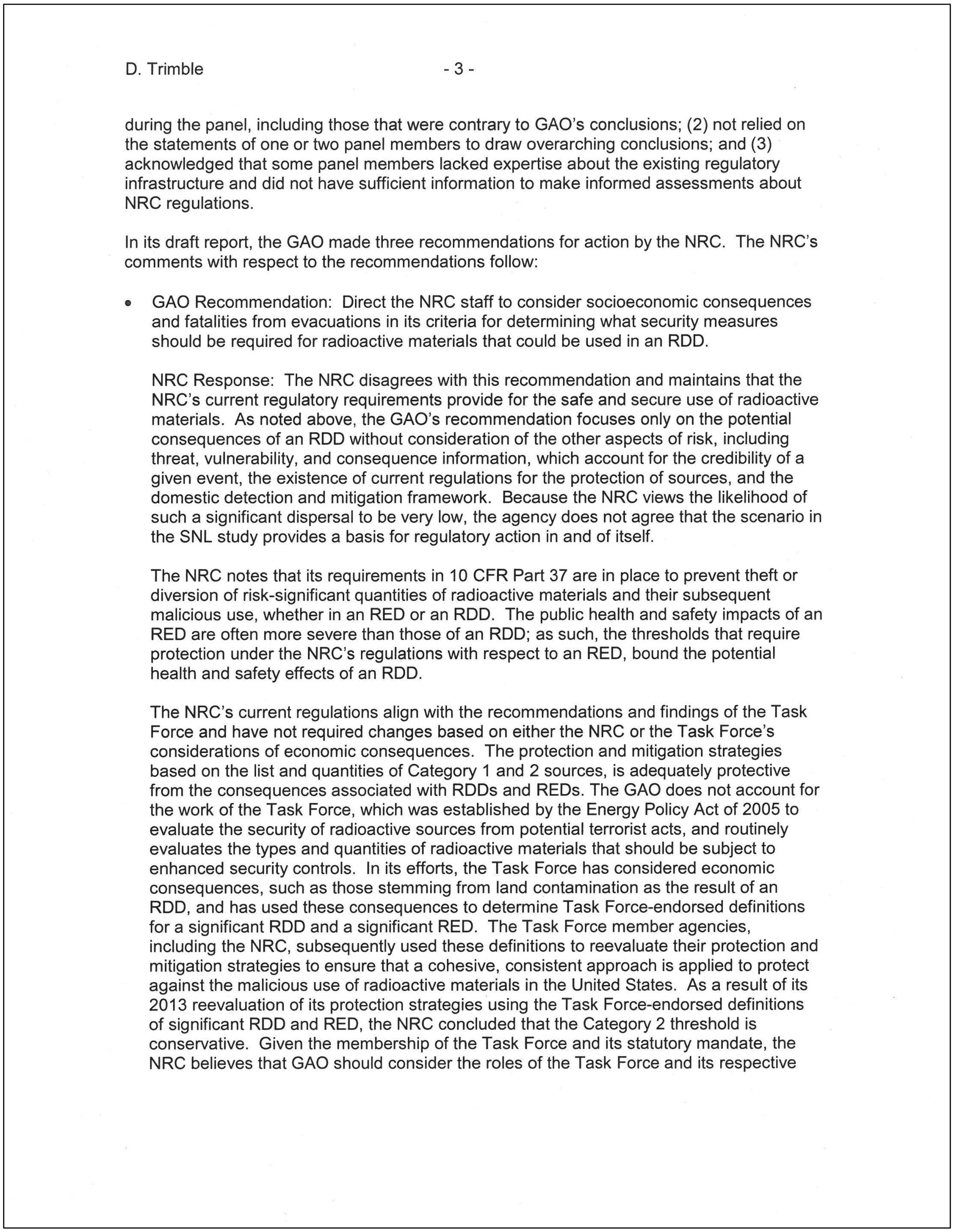
protect the country from potential terrorist threats, such as the use of radioactive material in a radiological dispersal device (RDD) or a radiation exposure device (RED). In October 2018, the Task Force submitted a report to the President and Congress (ADAMS Accession No. ML18276A155) in which the 14 Task Force member agencies concluded that there are no significant gaps in the area of radioactive source protection and security that are not already being addressed by ongoing efforts of the appropriate agencies.

In the subject draft report (GAO-19-258SU), the GAO staff present conclusions regarding the potential *consequences* of a RDD event without addressing the risk of such an event and use two primary reference sources to substantiate recommendations for further regulatory action. These sources include: (1) two studies that were prepared by Sandia National Laboratories (SNL) that seek to quantify the potential unmitigated socioeconomic effects of an RDD event; and (2) views expressed by members of a panel convened with the assistance of the National Academies of Sciences (NAS). In the draft report, the GAO staff concluded, based on these reference sources that the NRC's controls for protecting radioactive material from use in an RDD need to be strengthened because they were developed using the prevention of prompt fatalities and deterministic health effects as their consequence basis, rather than socioeconomic consequences. The GAO staff further concluded that the NRC should require additional security measures, in addition to the current regulations, for smaller quantities of radioactive material and circumstances in which multiple small quantities of radioactive material are collocated.

As explained below and in the enclosure, on the basis of its review, the NRC concluded that GAO's draft report and recommendations lack important context in that they focus on the potential consequences of an RDD without accounting for certain aspects of risk (i.e., threat and vulnerability), which include consideration of the probability of an event, the credible adversary capabilities, the protection afforded by the existing regulatory framework, and the sophisticated national infrastructure that is maintained under the leadership of DHS. In order to make risk-informed determinations regarding the appropriate level of safety and security controls to protect radioactive materials, it is necessary to consider all aspects of risk, and to assess the impact of any additional security measures on the beneficial use of radioactive materials.

Based on its thorough review of GAO's draft report and the Statement of Facts that preceded it, the NRC has also concluded that the GAO's primary references – namely, the two studies conducted by SNL and the views expressed during the NAS-facilitated panel – do not provide sufficient basis for the GAO's recommended regulatory and policy changes. The GAO uses malicious event scenarios from the studies, which are possible but not probable, to form the basis for the need for additional security requirements. In order to represent more realistic scenarios and outcomes, the studies should have: (1) been developed in coordination and cooperation with appropriate United States government agencies/departments; (2) used assumptions that, among other things, credit existing protective and mitigation capabilities; and (3) been subjected to a formal review and endorsement process.

The NRC also concluded that the GAO's characterization of the panel discussion did not reflect the views of all 18 panel members, and as such, the GAO's reliance on selected aspects of the panel discussion to form the primary basis for its recommendations resulted in conclusions that are not fully supported. In the NRC's view, a more balanced representation of the discussion would have: (1) included a summary of all views that were expressed



during the panel, including those that were contrary to GAO's conclusions; (2) not relied on the statements of one or two panel members to draw overarching conclusions; and (3) acknowledged that some panel members lacked expertise about the existing regulatory infrastructure and did not have sufficient information to make informed assessments about NRC regulations.

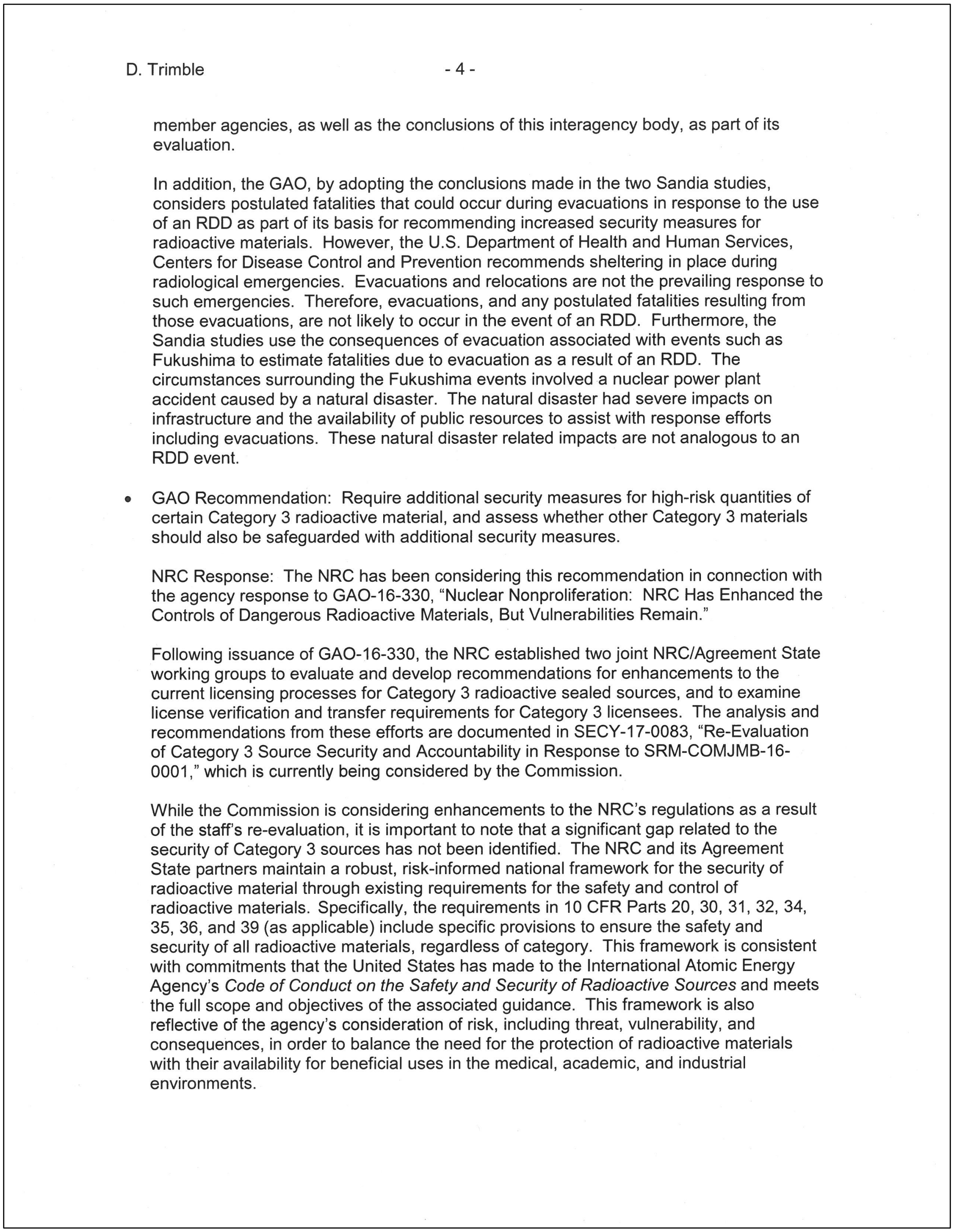
In its draft report, the GAO made three recommendations for action by the NRC. The NRC's comments with respect to the recommendations follow:

- GAO Recommendation: Direct the NRC staff to consider socioeconomic consequences and fatalities from evacuations in its criteria for determining what security measures should be required for radioactive materials that could be used in an RDD.

  NRC Response: The NRC disagrees with this recommendation and maintains that the NRC's current regulatory requirements provide for the safe and secure use of radioactive materials. As noted above, the GAO's recommendation focuses only on the potential consequences of an RDD without consideration of the other aspects of risk, including threat, vulnerability, and consequence information, which account for the credibility of a given event, the existence of current regulations for the protection of sources, and the domestic detection and mitigation framework. Because the NRC views the likelihood of such a significant dispersal to be very low, the agency does not agree that the scenario in the SNL study provides a basis for regulatory action in and of itself.

  The NRC notes that its requirements in 10 CFR Part 37 are in place to prevent theft or diversion of risk-significant quantities of radioactive materials and their subsequent malicious use, whether in an RED or an RDD. The public health and safety impacts of an RED are often more severe than those of an RDD; as such, the thresholds that require protection under the NRC's regulations with respect to an RED, bound the potential health and safety effects of an RDD.

  The NRC's current regulations align with the recommendations and findings of the Task Force and have not required changes based on either the NRC or the Task Force's considerations of economic consequences. The protection and mitigation strategies based on the list and quantities of Category 1 and 2 sources, is adequately protective from the consequences associated with RDDs and REDs. The GAO does not account for the work of the Task Force, which was established by the Energy Policy Act of 2005 to evaluate the security of radioactive sources from potential terrorist acts, and routinely evaluates the types and quantities of radioactive materials that should be subject to enhanced security controls. In its efforts, the Task Force has considered economic consequences, such as those stemming from land contamination as the result of an RDD, and has used these consequences to determine Task Force-endorsed definitions for a significant RDD and a significant RED. The Task Force member agencies, including the NRC, subsequently used these definitions to reevaluate their protection and mitigation strategies to ensure that a cohesive, consistent approach is applied to protect against the malicious use of radioactive materials in the United States. As a result of its 2013 reevaluation of its protection strategies using the Task Force-endorsed definitions of significant RDD and RED, the NRC concluded that the Category 2 threshold is conservative. Given the membership of the Task Force and its statutory mandate, the NRC believes that GAO should consider the roles of the Task Force and its respective



member agencies, as well as the conclusions of this interagency body, as part of its evaluation.

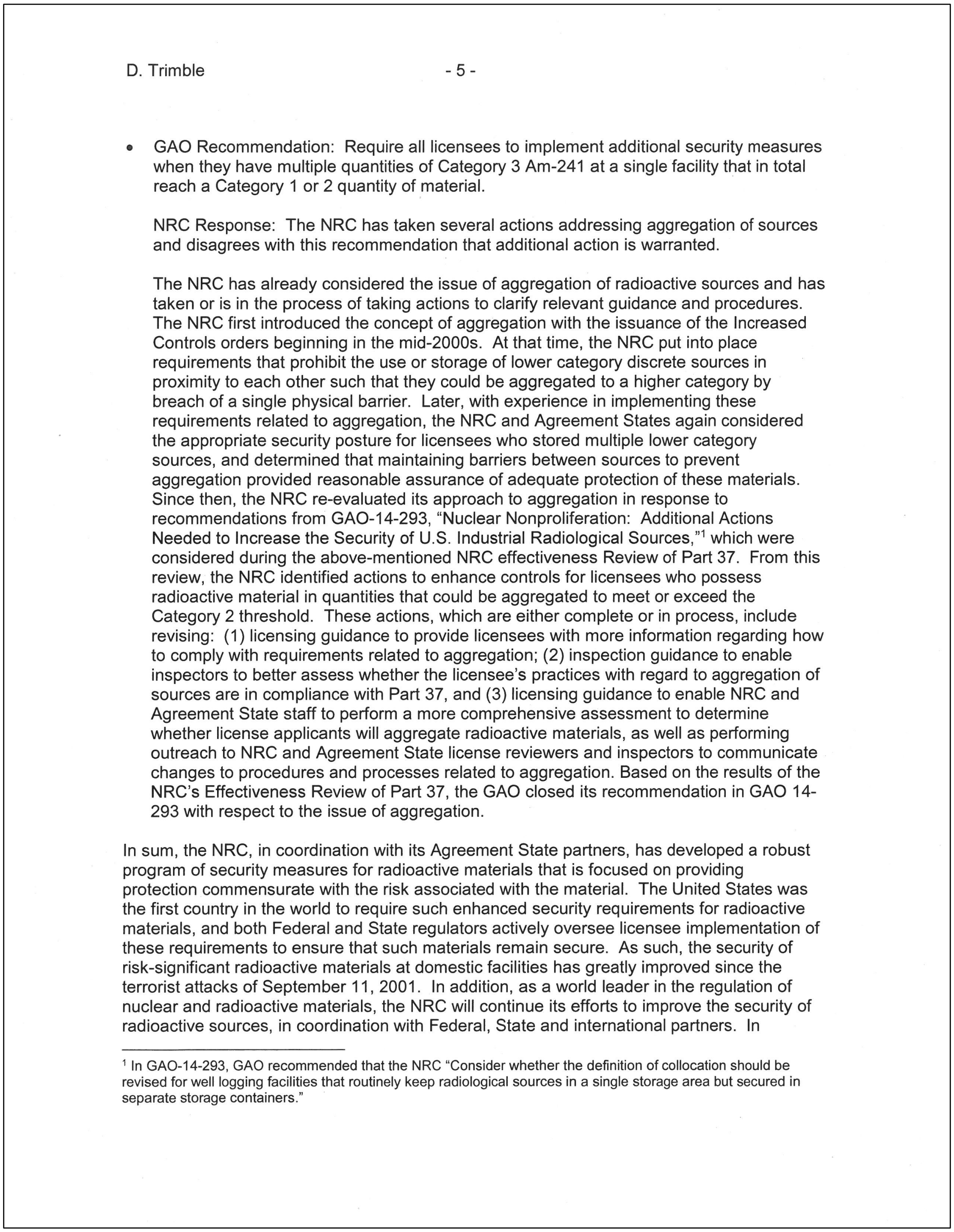
In addition, the GAO, by adopting the conclusions made in the two Sandia studies, considers postulated fatalities that could occur during evacuations in response to the use of an RDD as part of its basis for recommending increased security measures for radioactive materials. However, the U.S. Department of Health and Human Services, Centers for Disease Control and Prevention recommends sheltering in place during radiological emergencies. Evacuations and relocations are not the prevailing response to such emergencies. Therefore, evacuations, and any postulated fatalities resulting from those evacuations, are not likely to occur in the event of an RDD. Furthermore, the Sandia studies use the consequences of evacuation associated with events such as Fukushima to estimate fatalities due to evacuation as a result of an RDD. The circumstances surrounding the Fukushima events involved a nuclear power plant accident caused by a natural disaster. The natural disaster had severe impacts on infrastructure and the availability of public resources to assist with response efforts including evacuations. These natural disaster related impacts are not analogous to an RDD event.

- GAO Recommendation: Require additional security measures for high-risk quantities of certain Category 3 radioactive material, and assess whether other Category 3 materials should also be safeguarded with additional security measures.

  NRC Response: The NRC has been considering this recommendation in connection with the agency response to GAO-16-330, "Nuclear Nonproliferation: NRC Has Enhanced the Controls of Dangerous Radioactive Materials, But Vulnerabilities Remain."

  Following issuance of GAO-16-330, the NRC established two joint NRC/Agreement State working groups to evaluate and develop recommendations for enhancements to the current licensing processes for Category 3 radioactive sealed sources, and to examine license verification and transfer requirements for Category 3 licensees. The analysis and recommendations from these efforts are documented in SECY-17-0083, "Re-Evaluation of Category 3 Source Security and Accountability in Response to SRM-COMJMB-16-0001," which is currently being considered by the Commission.

  While the Commission is considering enhancements to the NRC's regulations as a result of the staff's re-evaluation, it is important to note that a significant gap related to the security of Category 3 sources has not been identified. The NRC and its Agreement State partners maintain a robust, risk-informed national framework for the security of radioactive material through existing requirements for the safety and control of radioactive materials. Specifically, the requirements in 10 CFR Parts 20, 30, 31, 32, 34, 35, 36, and 39 (as applicable) include specific provisions to ensure the safety and security of all radioactive materials, regardless of category. This framework is consistent with commitments that the United States has made to the International Atomic Energy Agency's *Code of Conduct on the Safety and Security of Radioactive Sources* and meets the full scope and objectives of the associated guidance. This framework is also reflective of the agency's consideration of risk, including threat, vulnerability, and consequences, in order to balance the need for the protection of radioactive materials with their availability for beneficial uses in the medical, academic, and industrial environments.



- GAO Recommendation: Require all licensees to implement additional security measures when they have multiple quantities of Category 3 Am-241 at a single facility that in total reach a Category 1 or 2 quantity of material.

  NRC Response: The NRC has taken several actions addressing aggregation of sources and disagrees with this recommendation that additional action is warranted.

  The NRC has already considered the issue of aggregation of radioactive sources and has taken or is in the process of taking actions to clarify relevant guidance and procedures. The NRC first introduced the concept of aggregation with the issuance of the Increased Controls orders beginning in the mid-2000s. At that time, the NRC put into place requirements that prohibit the use or storage of lower category discrete sources in proximity to each other such that they could be aggregated to a higher category by breach of a single physical barrier. Later, with experience in implementing these requirements related to aggregation, the NRC and Agreement States again considered the appropriate security posture for licensees who stored multiple lower category sources, and determined that maintaining barriers between sources to prevent aggregation provided reasonable assurance of adequate protection of these materials. Since then, the NRC re-evaluated its approach to aggregation in response to recommendations from GAO-14-293, "Nuclear Nonproliferation: Additional Actions Needed to Increase the Security of U.S. Industrial Radiological Sources,"[1] which were considered during the above-mentioned NRC effectiveness Review of Part 37. From this review, the NRC identified actions to enhance controls for licensees who possess radioactive material in quantities that could be aggregated to meet or exceed the Category 2 threshold. These actions, which are either complete or in process, include revising: (1) licensing guidance to provide licensees with more information regarding how to comply with requirements related to aggregation; (2) inspection guidance to enable inspectors to better assess whether the licensee's practices with regard to aggregation of sources are in compliance with Part 37, and (3) licensing guidance to enable NRC and Agreement State staff to perform a more comprehensive assessment to determine whether license applicants will aggregate radioactive materials, as well as performing outreach to NRC and Agreement State license reviewers and inspectors to communicate changes to procedures and processes related to aggregation. Based on the results of the NRC's Effectiveness Review of Part 37, the GAO closed its recommendation in GAO 14-293 with respect to the issue of aggregation.

In sum, the NRC, in coordination with its Agreement State partners, has developed a robust program of security measures for radioactive materials that is focused on providing protection commensurate with the risk associated with the material. The United States was the first country in the world to require such enhanced security requirements for radioactive materials, and both Federal and State regulators actively oversee licensee implementation of these requirements to ensure that such materials remain secure. As such, the security of risk-significant radioactive materials at domestic facilities has greatly improved since the terrorist attacks of September 11, 2001. In addition, as a world leader in the regulation of nuclear and radioactive materials, the NRC will continue its efforts to improve the security of radioactive sources, in coordination with Federal, State and international partners. In

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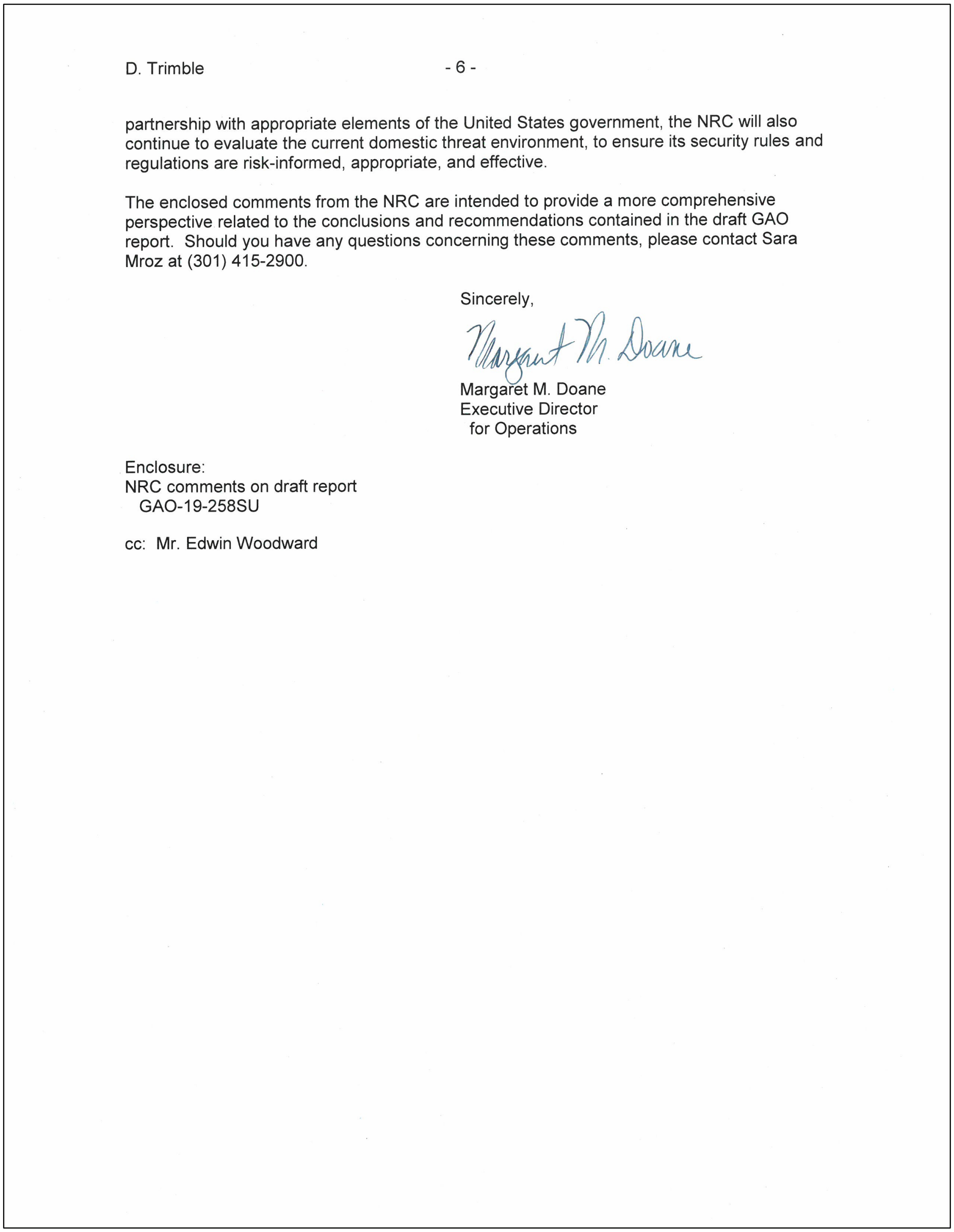
[1] In GAO-14-293, GAO recommended that the NRC "Consider whether the definition of collocation should be revised for well logging facilities that routinely keep radiological sources in a single storage area but secured in separate storage containers."



partnership with appropriate elements of the United States government, the NRC will also continue to evaluate the current domestic threat environment, to ensure its security rules and regulations are risk-informed, appropriate, and effective.

The enclosed comments from the NRC are intended to provide a more comprehensive perspective related to the conclusions and recommendations contained in the draft GAO report. Should you have any questions concerning these comments, please contact Sara Mroz at (301) 415-2900.

Sincerely,

Margaret M. Doane

Margaret M. Doane
Executive Director
for Operations

Enclosure:
NRC comments on draft report
GAO-19-258SU

cc: Mr. Edwin Woodward

Appendix IV: GAO Contact and Staff Acknowledgments

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Staff Acknowledgments

In addition to the individual named above, Ned Woodward (Assistant Director), Jeffrey Barron (Analyst in Charge), Kevin Bray, Mark Braza, Kendall Childers, Tara Congdon, Gabrielle Matuzsan, Amanda Miller, Danny Royer, and Kiki Theodoropoulos made key contributions to this report.

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